UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

STEPHEN McCOLLUM, and SANDRA McCOLLUM, individually, and STEPHANIE KINGREY, individually and as independent administrator of the Estate of LARRY GENE McCOLLUM, PLAINTIFFS	§ § § § § § §	
v.	§	CIVIL ACTION NO. 4:14-cv-3253 JURY DEMAND
BRAD LIVINGSTON, JEFF PRINGLE, RICHARD CLARK, KAREN TATE, SANDREA SANDERS, ROBERT EASON, the UNIVERSITY OF TEXAS MEDICAL BRANCH and the TEXAS DEPARTMENT OF CRIMINAL JUSTICE. DEFENDANTS	§ § § § § § § § §	

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4-4152

Revised August 2007. (Existing) Circulation is at least ten cubic feet of fresh or re-circulated filtered air per minute per occupant for inmate rooms/cells, officer stations, and dining areas, as documented by a qualified technician and should be checked not less than once per accreditation cycle.

Interpretation August 2002. The words *accreditation cycle* are interpreted as within the past three years.

COMMENT: None.

4-4153

Revised August 2006. Temperatures in indoor living and work areas are appropriate to the summer and winter comfort zones.

COMMENT: Temperature should be capable of being mechanically raised or lowered to an acceptable comfort level.

4-4155

Revised August 2004. Segregation units have either outdoor uncovered or outdoor covered exercise areas. The minimum space requirements for outdoor exercise areas for segregation units are as follows:

- **group yard modules: 15 square feet per inmate expected to use the space at one time, but not less than 500 square feet of unencumbered space**
- **individual yard modules: 180 square feet of unencumbered space in cases where cover is not provided to mitigate the inclement weather, appropriate weather-related equipment and attire should be made available to the inmates who desire to take advantage of their authorized exercise time.**

COMMENT: None.

4-4170

Deleted January 2007.

4-4174

Revised August 2009. There is a manual containing all procedures for institutional security and control, with detailed instructions for implementing these procedures. The manual is available to all staff.

COMMENT: The manual should contain information on physical plant inspection, inmate counts, weapons and chemical agent control, contraband, key control, tool and equipment control, and emergency procedures.

Δ π EXHIBIT 13
Deponent
Date Rptr.
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UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

STEPHEN McCOLLUM, and SANDRA McCOLLUM, individually, and STEPHANIE KINGREY, individually and as independent administrator of the Estate of LARRY GENE McCOLLUM, PLAINTIFFS	§ § § § § § §	
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Plaintiffs' Consolidated Summary Judgment Response Appendix

EXHIBIT 145

		Health Care Outcomes		
Standard	Outcome Measure	Numerator/Denominator	Value	Calcu-lated O.M.
1A	(1)	Number of offenders diagnosed with a MRSA infection within the past twelve (12) months	109	
	divided by	The average daily population	1968	5.54%
	(2)	Number of offenders diagnosed with active tuberculosis in the past twelve (12) months	1	
	divided by	Average daily population.	109	0.92%
	(3)	Number of offenders who are new converters on a TB test that indicates newly acquired TB infection in the past twelve (12) months	18	
	divided by	Number of offenders administered tests for TB infection in the past twelve (12) months as part of periodic or clinically-based testing, but not intake screening.	83	21.69%
	(4)	Number of offenders who completed treatment for latent tuberculosis infection in the past twelve (12) months	23	
	divided by	Number of offenders treated for latent tuberculosis infection in the past twelve (12) months.	112	20.54%
	(5)	Number of offenders diagnosed with Hepatitis C viral infection at a given point in time	180	
	divided by	Total offender population at that time.	1927	9.34%
	(6)	Number of offenders diagnosed with HIV infection at a given point in time	34	
	divided by	Total offender population at that time.	1927	1.76%
	(7)	Number of offenders with HIV infection who are being treated with highly active antiretroviral treatment (HAART) at a given point in time	14	
	divided by	Total number of offenders diagnosed with HIV infection at that time.	34	41.18%
	(8)	Number of selected offenders with HIV infection at a given point in time who have been on antiretroviral therapy for at least six months with a viral load of less than 50 cps/ml	2	
	divided by	Total number of treated offenders with HIV infection that were reviewed.	34	5.88%
	(9)	Number of offenders diagnosed with an Axis I disorder (excluding sole diagnosis of substance abuse) at a given point in time	136	

	divided by	Total offender population at that time.	1927	7.06%
	(10)	Number of offender admissions to off-site hospitals in the past twelve (12) months	16	
	divided by	Average daily population.	1968	0.81%
	(11)	Number of offenders transported off-site for treatment of emergency health conditions in the past twelve (12) months	122	
	divided by	Average daily population in the past twelve (12) months.	1968	6.20%
	(12)	Number of offender specialty consults completed during the past twelve (12) months	236	
	divided by	Number of specialty consults (on-site or off-site) ordered by primary health care practitioners in the past twelve (12) months.	313	75.40%
	(13)	Number of selected hypertensive offenders at a given point in time with a B/P reading > 140 mmHg/ >90 mm Hg	99	
	divided by	Total number of offenders with hypertension who were reviewed.	226	43.81%
	(14)	Number of selected diabetic offenders at a given point in time who are under treatment for at least six months with a hemoglobin A1C level measuring greater than 9 percent	0	
	divided by	Total number of diabetic offenders who were reviewed.	57	0.00%
	(15)	The number of completed dental treatment plans within the past twelve (12) months	136	
	divided by	the average daily population during the reporting period.	1968	6.91%
2A	(1)	Number of health care staff with lapsed licensure or certification during a twelve (12) month period	0	
	divided by	Number of licensed or certified staff during a twelve (12) month period.	25	0.00%
	(2)	Number of new health care staff during a twelve (12) month period that completed orientation training prior to undertaking their job	7	
	divided by	Number of new health care staff during the twelve (12) month period.	7	100.00%
	(3)	Number of occupational exposures to blood or other potentially infectious materials in the past twelve (12) months	2	
	divided by	Number of employees.	33	6.05%
	(4)	Number of direct care staff (employees and contractors) with a conversion of a TB test that indicates newly acquired TB infection in the past twelve (12) months	0	
	divided by	Number of direct care staff tested for TB infection in the past twelve (12) months during periodic or clinically indicated evaluations.	2	0.00%
3A	(1)	Number of offender grievances related to health care services found in favor of the offender in the past twelve (12) months	15	
	divided by	Number of evaluated offender grievances related to health care services in the past twelve (12) months.	71	21.13%

	(2)	Number of offender grievances related to safety or sanitation sustained during a twelve (12) month period	4	
	divided by	Number of evaluated offender grievances related to safety or sanitation during a twelve (12) month period.	14	28.57%
	(3)	Number of adjudicated offender lawsuits related to the delivery of health care found in favor of the offender in the past twelve (12) months	0	
	divided by	Number of offender adjudicated lawsuits related to healthcare delivery in the past twelve (12) months	0	#DIV/O1
4A	(1)	Number of problems identified by quality assurance program that were corrected during a twelve (12) month period	5	
	divided by	Number of problems identified by quality assurance program during a twelve (12) month period.	4	125.00%
	(2)	Number of high-risk events or adverse outcomes identified by the quality assurance program during a twelve (12) month period.	0	
	(3)	Number of offender suicide attempts in the past twelve (12) months	1	
	divided by	Average daily population	1968	0.05%
	(4)	Number of offender suicides in the past twelve (12) months	0	
	divided by	Average daily population	1968	0.00%
	(5)	Number of unexpected natural deaths in the past twelve (12) months	1	
	divided by	Total number of deaths in the same reporting period.	1	
	(6)	Number of serious medication errors in the past twelve (12) months	0	
5A	None			
6A	None			
7A	None			
7B	None			
7C	None			

From: Tina Carmona/Institutional/TDCJ
To: Carol Cozart/Institutional/TDCJ

Date: Wednesday, May 12, 2010 10:17AM
Subject: Fw: ACA Final Report

Please print this and all attachments. Be sure to give copy to ACA for files.

Russell Bailey

----- Original Message -----
From: Russell Bailey
Sent: 05/12/2010 10:16 AM CDT
To: Tina Carmona
Cc: pamager@utmb.edu
Subject: ACA Final Report

Warden Carmona,
Attached below is the ACA Final Report for the Hutchins Unit. We no longer mail out a hard copy, so please print the report, and ensure that a copy is maintained in the ACA Office. The Panel Hearing Minutes are located on page 28. Again, congratulations to you and your staff on your Reaccreditation.

Russell Bailey, Administrator
TDCJ Monitoring & Standards

Attachments:

Hutchins Unit Final Report.pdf

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DEFENDANTS	§	

Plaintiffs' Consolidated Summary Judgment Response Appendix

EXHIBIT 146

ANSI/ASHRAE Standard 55-2004
(Supersedes ANSI/ASHRAE Standard 55-1992)

ASHRAE STANDARD

Thermal Environmental Conditions for Human Occupancy

Approved by the ASHRAE Standards Committee on January 24, 2004; by the ASHRAE Board of Directors on January 29, 2004; and by the American National Standards Institute on April 16, 2004.

ASHRAE Standards are scheduled to be updated on a five-year cycle; the date following the standard number is the year of ASHRAE Board of Directors approval. The latest copies may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: *orders@ashrae.org.* Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in U.S. and Canada).

ISSN 1041-2336

When addenda or interpretations to this standard have been approved, they can be downloaded free of charge from the ASHRAE web site at http://www.ashrae.org/template/TechnologyLinkLanding/category/1631 or http://www.ashrae.org/template/TechnologyLinkLanding/category/1686.

Approved American National Standard
ANSI

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
1791 Tullie Circle, NE • Atlanta, GA 30329

SPECIAL NOTE

This American National Standard (ANS) is a national voluntary consensus standard developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Consensus is defined by the American National Standards Institute (ANSI), of which ASHRAE is a member and which has approved this standard as an ANS, as "substantial agreement reached by directly and materially affected interest categories. This signifies the concurrence of more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution." Compliance with this standard is voluntary until and unless a legal jurisdiction makes compliance mandatory through legislation.

ASHRAE obtains consensus through participation of its national and international members, associated societies, and public review.

ASHRAE Standards are prepared by a Project Committee appointed specifically for the purpose of writing the Standard. The Project Committee Chair and Vice-Chair must be members of ASHRAE; while other committee members may or may not be ASHRAE members, all must be technically qualified in the subject area of the Standard. Every effort is made to balance the concerned interests on all Project Committees.

The Manager of Standards of ASHRAE should be contacted for:

a. interpretation of the contents of this Standard,
b. participation in the next review of the Standard,
c. offering constructive criticism for improving the Standard,
d. permission to reprint portions of the Standard.

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CONTENTS

ANSI/ASHRAE Standard 55-2004
Thermal Environmental Conditions for Human Occupancy

1791 Tullie Circle NE
Atlanta, GA 30329
www.ashrae.org

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

FOREWORD

Standard 55-2004, "Thermal Environmental Conditions for Human Occupancy," is a revision of Standard 55-1992. The standard specifies conditions in which a specified fraction of the occupants will find the environment thermally acceptable. The revision is a consensus standard that has undergone public and ASHRAE review; it incorporates the relevant research and experience gained since the 1992 revision. Such changes include the addition of the PMV/PPD calculation methods and the concept of adaptation. The standard is intended for use in design, commissioning, and testing of buildings and other occupied spaces and their HVAC systems and for the evaluation of thermal environments. Because it is not possible to prescribe the metabolic rate of occupants, and because of variations in occupant clothing levels, operating setpoints for buildings cannot be practically mandated by this standard.

The designer may choose, in agreement with the owner or owner's representative (e.g., owner's agent, developer, or equivalent), the level of thermal comfort and appropriate exceedance. The selected design criteria will influence the HVAC system design and may also influence the building design. This standard may also be used for evaluation of existing thermal environments in buildings, during experimental conditions, and for the development and testing of products.

This standard is in close agreement with ISO Standards 7726[1] and 7730.[2]

1. PURPOSE

The purpose of this standard is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space.

2. SCOPE

2.1 The environmental factors addressed in this standard are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing.

2.2 It is intended that all of the criteria in this standard be applied together since comfort in the indoor environment is complex and responds to the interaction of all of the factors that are addressed.

2.3 This standard specifies thermal environmental conditions acceptable for healthy adults at atmospheric pressure equivalent to altitudes up to 3000 m (10,000 ft) in indoor spaces designed for human occupancy for periods not less than 15 minutes.

2.4 This standard does not address such nonthermal environmental factors as air quality, acoustics, and illumination or other physical, chemical, or biological space contaminants that may affect comfort or health.

3. DEFINITIONS

adaptive model: a model that relates indoor design temperatures or acceptable temperature ranges to outdoor meteorological or climatalogical parameters.

air speed: the rate of air movement at a point, without regard to direction.

clo: a unit used to express the thermal insulation provided by garments and clothing ensembles, where 1 clo = 0.155 m^2 °C/W (0.88 ft^2·h·°F/Btu).

comfort, thermal: that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

draft: the unwanted local cooling of the body caused by air movement.

draft rate (DR): percentage of people predicted to be dissatisfied due to draft.

environment, thermal: the characteristics of the environment that affect a person's heat loss.

environment, acceptable thermal: an environment that a substantial majority of the occupants would find thermally acceptable.

garment: a single piece of clothing.

humidity ratio: the ratio of the mass of water vapor to the mass of dry air in a given volume.

humidity, relative (RH): the ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure.

insulation, clothing/ensemble (I_{cl}): the resistance to sensible heat transfer provided by a clothing ensemble. Expressed in clo units. ***Note:*** The definition of clothing insulation relates to heat transfer from the whole body and, thus, also includes the uncovered parts of the body, such as head and hands.

insulation, garment (I_{clu}): the increased resistance to sensible heat transfer obtained from adding an individual garment over the nude body. Expressed in clo units.

met: a unit used to describe the energy generated inside the body due to metabolic activity, defined as 58.2 W/m^2 (18.4 Btu/h·ft^2), which is equal to the energy produced per unit surface area of an average person, seated at rest. The surface area of an average person is 1.8 m^2 (19 ft^2).

metabolic rate (M): the rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface. In this standard, this rate is expressed in met units.

naturally conditioned spaces, occupant controlled: those spaces where the thermal conditions of the space are regulated primarily by the opening and closing of windows by the occupants.

neutrality, thermal: the indoor thermal index value corresponding with a mean vote of neutral on the thermal sensation scale.

percent dissatisfied (PD): percentage of people predicted to be dissatisfied due to local discomfort.

predicted mean vote (PMV): an index that predicts the mean value of the votes of a large group of persons on the seven-point thermal sensation scale.

predicted percentage of dissatisfied (PPD): an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV.

radiant temperature asymmetry: the difference between the plane radiant temperature of the two opposite sides of a small plane element.

response time (90%): the time for a measuring sensor to reach 90% of the final value after a step change. For a measuring system that includes only one exponential time-constant function, the 90% response time equals 2.3 times the "time constant."

sensation, thermal: a conscious feeling commonly graded into the categories *cold*, *cool*, *slightly cool*, *neutral*, *slightly warm*, *warm*, and *hot*; it requires subjective evaluation.

step change: an incremental change in a variable, either by design or as the result of an interval between measurement; typically, an incremental change in a control setpoint.

temperature, air (t_a): the temperature of the air surrounding the occupant.

temperature, dew point (t_{dp}): the temperature at which moist air becomes saturated (100% relative humidity) with water vapor ($p_{sdp} = p_a$) when cooled at constant pressure.

temperature, mean monthly outdoor air ($t_{a(out)}$): when used as input variable in Figure 5.3.1 for the adaptive model, this temperature is based on the arithmetic average of the mean daily minimum and mean daily maximum outdoor (dry-bulb) temperatures for the month in question.

temperature, mean radiant (t_r): the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual nonuniform space; see Section 7.2 for information on measurement positions.

temperature, operative (t_o): the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment; see Section 7.2 for information on body position within the imaginary enclosure.

temperature, plane radiant (t_{pr}): the uniform temperature of an enclosure in which the incident radiant flux on one side of a small plane element is the same as in the existing environment.

time constant: the time for a measuring sensor to reach 63% of the final value after a step change.

turbulence intensity (Tu): the ratio of the standard deviation of the air speed (SD_v) to the mean air speed (v). Turbulence intensity may also be expressed in percent (i.e., $Tu = [SD_v / v_a] \cdot 100$).

water vapor pressure (p_a): the pressure that the water vapor would exert if it alone occupied the volume occupied by the humid air at the same temperature.

water vapor pressure, saturated dewpoint (p_{sdp}): the water vapor pressure at the saturation temperature corresponding to the reference pressure and without any liquid phase.

velocity, mean (v_a): an average of the instantaneous air velocity over an interval of time.

velocity, standard deviation (SD_v): a measure of the scatter of the instantaneous air velocity around the mean air velocity in a frequency distribution, defined as the square root of the arithmetic average of a set of square values of the difference between the instantaneous air velocity and the mean air velocity. The standard deviation is based on individual values of air speed that represent an average over no more than two seconds each.

zone, occupied: the region normally occupied by people within a space, generally considered to be between the floor and 1.8 m (6 ft) above the floor and more than 1.0 m (3.3 ft) from outside walls/windows or fixed heating, ventilating, or air-conditioning equipment and 0.3 m (1 ft) from internal walls.

4. GENERAL REQUIREMENTS

Use of this standard is specific to the space being considered and the occupants of that space. Any application of this standard must specify the space to which it applies or the locations within that space to which it applies, if not to the entire space. Any application of this standard must identify the occupants (who must have a residency of more than 15 minutes in the space) to which it applies.

The activity and clothing of the occupants must be considered in applying this standard. When there are substantial differences in physical activity and/or clothing for occupants of a space, these differences must be considered.

It may not be possible to achieve an acceptable thermal environment for all occupants of a space due to individual differences, including activity and/or clothing. If the requirements are not met for some known set of occupants, then these occupants must be identified.

The thermal environmental conditions required for comfort are determined according to Section 5.2 or Section 5.3 of this standard. Any application of this standard must clearly state which of these sections is used. Additionally, all requirements of the applicable section, 5.2 or 5.3, must be met.

5. CONDITIONS THAT PROVIDE THERMAL COMFORT

5.1 Introduction

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space. The environmental conditions required for comfort are not the same for everyone. However, extensive laboratory and field data have been collected that provide the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable. Section 5 of this standard is used to determine the thermal environmental conditions in a space that are necessary to achieve acceptance by a specified percentage of occupants of that space.

There are six primary factors that must be addressed when defining conditions for thermal comfort. A number of other, secondary factors affect comfort in some circumstances. The six primary factors are listed below. Complete descriptions of these factors are presented in Section 5.4 and Appendices A and B.

1. Metabolic rate
2. Clothing insulation
3. Air temperature
4. Radiant temperature
5. Air speed
6. Humidity

All six of these factors may vary with time. However, this standard only addresses thermal comfort in a steady state (with some limited specifications for temperature variations with time in Section 5.2.5). As a result, people entering a space that meets the requirements of this standard may not immediately find the conditions comfortable if they have experienced different environmental conditions just prior to entering the space. The effect of prior exposure or activity may affect comfort perceptions for approximately one hour.

Factors 2 through 6 may be nonuniform over an occupant's body, and this nonuniformity may be an important consideration in determining thermal comfort. Nonuniformity is addressed in Section 5.2.4.

The vast majority of the available thermal comfort data pertains to sedentary or near sedentary physical activity levels typical of office work. This standard is intended primarily for these conditions. However, it may also be used to determine appropriate environmental conditions for moderately elevated activity. It does not apply to sleeping or bed rest. The body of available data does not contain significant information regarding the comfort requirements of children, the disabled, or the infirm. However, the information in this standard can often be applied to these types of occupants if it is applied judiciously to groups of occupants such as are found in classroom situations.

Section 5.2 contains the methodology that shall be used for most applications. However, the conditions required for thermal comfort in spaces that are naturally conditioned are not necessarily the same as those conditions required for other indoor spaces. Field experiments have shown that in naturally conditioned spaces, where occupants have control of operable windows, the subjective notion of comfort is different because of different thermal experiences, availability of control, and resulting shifts in occupant expectations. Section 5.3 specifies criteria required for a space to be considered naturally conditioned. The methods of Section 5.3 may, as an option, be applied to spaces that meet these criteria. The methods of Section 5.3 may not be applied to other spaces.

Section 5.4 describes in some detail variables that must be clearly understood in order to use the methods of Section 5 effectively.

5.2 Method for Determining Acceptable Thermal Conditions in Occupied Spaces

When Section 5.2 is used to determine the requirements for thermal comfort, the requirements of all subsections—5.2.1, 5.2.2, 5.2.3, 5.2.4, and 5.2.5—must be met. This standard recommends a specific percentage of occupants that constitutes acceptability and values of the thermal environment associated with this percentage.

5.2.1 Operative Temperature. For given values of humidity, air speed, metabolic rate, and clothing insulation, a comfort zone may be determined. The comfort zone is defined in terms of a range of operative temperatures that provide acceptable thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that people find thermally acceptable.

This section describes methods that may be used to determine temperature limits for the comfort zone. Section 5.2.1.1 uses a simplified graphical method for determining the comfort zone that may be used for many typical applications. Section 5.2.1.2 uses a computer program based on a heat balance model to determine the comfort zone for a wider range of applications. For a given set of conditions, the results from the two methods are consistent, and either method may be used as long as the criteria outlined in the respective section are met.

See Appendix C and the *2001 ASHRAE Handbook—Fundamentals*,[3] Chapter 8, for procedures to calculate operative temperature. Dry-bulb temperature may be used as a proxy for operative temperature under certain conditions described in Appendix C.

5.2.1.1 Graphical Method for Typical Indoor Environments. The method in this section may be applied to spaces where the occupants have activity levels that result in metabolic rates between 1.0 met and 1.3 met and where clothing is worn that provides between 0.5 clo and 1.0 clo of thermal insulation. See Appendix A for estimation of metabolic rates and Appendix B for estimation of clothing insulation. Most office spaces fall within these limitations.

The range of operative temperatures presented in Figure 5.2.1.1 are for 80% occupant acceptability. This is based on a 10% dissatisfaction criteria for general (whole body) thermal

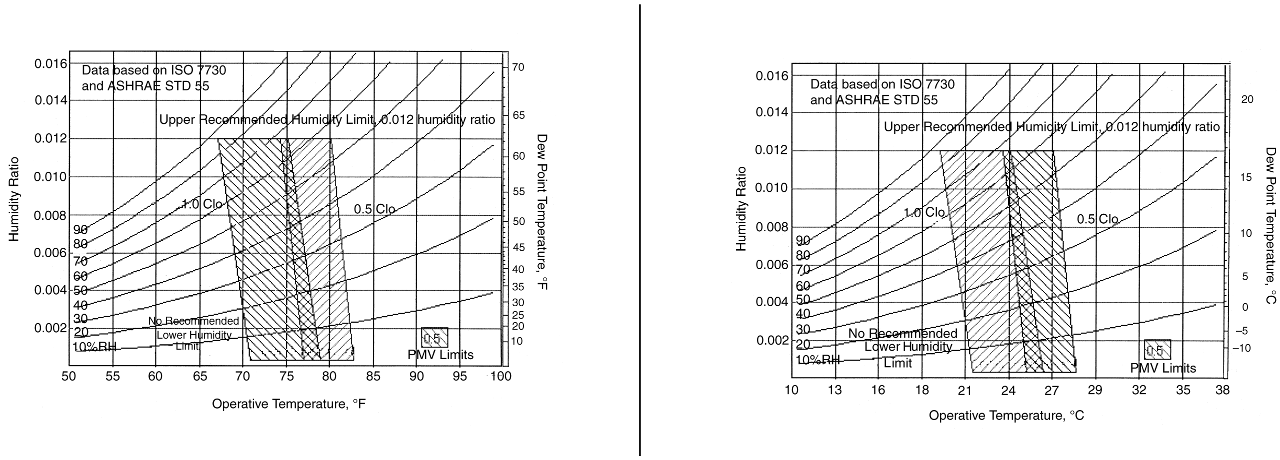

Figure 5.2.1.1 Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.

comfort based on the PMV-PPD index, plus an additional 10% dissatisfaction that may occur on average from local (partial body) thermal discomfort. Appendix D provides a list of inputs and outputs used in the PMV/PPD computer program to generate these graphs.

Figure 5.2.1.1 specifies the comfort zone for environments that meet the above criteria and where the air speeds are not greater than 0.20 m/s (40 ft/min). Two zones are shown—one for 0.5 clo of clothing insulation and one for 1.0 clo of insulation. These insulation levels are typical of clothing worn when the outdoor environment is warm and cool, respectively. The operative temperature range allowed for intermediate values of clothing insulation may be determined by linear interpolation between the limits for 0.5 clo and 1.0 clo, using the following relationships:

$$T_{min,\ Icl} = [(I_{cl} - 0.5\text{ clo})\ T_{min,\ 1.0\ clo} + (1.0\text{ clo} - I_{cl})\ T_{min,\ 0.5clo}]\ /\ 0.5\text{ clo}$$

$$T_{max,\ Icl} = [(I_{cl} - 0.5\text{ clo})\ T_{max,\ 1.0\ clo} + (1.0\text{ clo} - I_{cl})\ T_{max,\ 0.5clo}]\ /\ 0.5\text{ clo}$$

where

$T_{max,\ Icl}$ = upper operative temperature limit for clothing insulation I_{cl},

$T_{min,\ Icl}$ = lower operative temperature limit for clothing insulation I_{cl}, and

I_{cl} = thermal insulation of the clothing in question (clo).

Air speeds greater than 0.20 m/s (40 ft/min) may be used to increase the upper operative temperature limit for the comfort zone in certain circumstances. Section 5.2.3 describes these adjustments and specifies the criteria required for such adjustments.

5.2.1.2 Computer Model Method for General Indoor Application. The method in this section may be applied to spaces where the occupants have activity levels that result in average metabolic rates between 1.0 met and 2.0 met and where clothing is worn that provides 1.5 clo or less of thermal

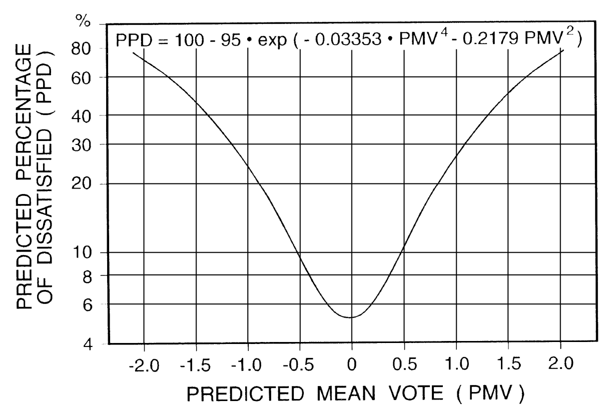

Figure 5.2.1.2 Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).

insulation. See Appendix A for estimation of metabolic rates and Appendix B for estimation of clothing insulation.

The ASHRAE thermal sensation scale, which was developed for use in quantifying people's thermal sensation, is defined as follows:

+3 hot
+2 warm
+1 slightly warm
0 neutral
–1 slightly cool
–2 cool
–3 cold

The predicted mean vote (PMV) model uses heat balance principles to relate the six key factors for thermal comfort listed in Section 5.1 to the average response of people on the above scale. The PPD (predicted percentage of dissatisfied) index is related to the PMV as defined in Figure 5.2.1.2. It is based on the assumption that people voting +2, +3, –2, or –3

TABLE 5.2.1.2
Acceptable Thermal Environment for General Comfort

PPD	PMV Range
< 10	-0.5 < PMV < + 0.5

on the thermal sensation scale are dissatisfied, and the simplification that PPD is symmetric around a neutral PMV.

Table 5.2.1.2 defines the recommended PPD and PMV range for typical applications. This is the basis for the graphical method in Section 5.2.1.1.

The comfort zone is defined by the combinations of air temperature and mean radiant temperature for which the PMV is within the recommended limits specified in Table 5.2.1.2. The PMV model is calculated with the air temperature and mean radiant temperature in question along with the applicable metabolic rate, clothing insulation, air speed, and humidity. If the resulting PMV value generated by the model is within the recommended range, the conditions are within the comfort zone.

Use of the PMV model in this standard is limited to air speeds not greater than 0.20 m/s (40 fpm). Air speeds greater than 0.20 m/s (40 ft/min) may be used to increase the upper temperature limits of the comfort zone in certain circumstances. Section 5.2.3 describes these adjustments and specifies the criteria required for such adjustments. The adjustments in Section 5.2.3 are with respect to the upper limit of the comfort zone determined with the PMV model using an air speed of 0.20 m/s (40 fpm).

There are several computer codes available that predict PMV-PPD. The computer code in Appendix D is to be used with this standard.[4] If any other version is used, it is the user's responsibility to verify and document that the version used yields the same results as the code in Appendix D for the conditions for which it is applied.

5.2.2 Humidity Limits. Systems designed to control humidity shall be able to maintain a humidity ratio at or below 0.012, which corresponds to a water vapor pressure of 1.910 kPa (0.277 psi) at standard pressure or a dew-point temperature of 16.8°C (62.2°F).

There are no established lower humidity limits for thermal comfort; consequently, this standard does not specify a minimum humidity level. However, non-thermal comfort factors, such as skin drying, irritation of mucus membranes, dryness of the eyes, and static electricity generation, may place limits on the acceptability of very low humidity environments.

5.2.3 Elevated Air Speed. Precise relationships between increased air speed and improved comfort have not been established. However, this standard allows elevated air speed to be used to increase the maximum temperature for acceptability if the affected occupants are able to control the air speed. The amount that the temperature may be increased is shown in Figure 5.2.3. The combinations of air speed and temperature defined by the lines in this figure result in the same heat loss from the skin. The reference point for these curves is the upper temperature limit of the comfort zone (PMV = +0.5) and 0.20 m/s (40 fpm) of air speed. This figure applies to a lightly clothed person (with clothing insulation between 0.5 clo and 0.7 clo) who is engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met).

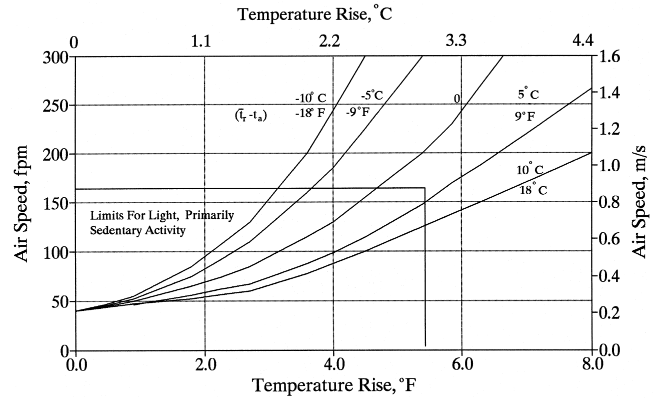

Figure 5.2.3 Air speed required to offset increased temperature.

The indicated increase in temperature pertains to both the mean radiant temperature and the air temperature. That is, both temperatures increase by the same amount with respect to the starting point. When the mean radiant temperature is low and the air temperature is high, elevated air speed is less effective at increasing heat loss. Conversely, elevated air speed is more effective at increasing heat loss when the mean radiant temperature is high and the air temperature is low. Thus, the curve in Figure 5.2.3 that corresponds to the relative difference between air temperature and mean radiant temperature must be used. It is acceptable to interpolate between curves for intermediate differences.

Elevated air speed may be used to offset an increase in the air temperature and the mean radiant temperature, but not by more than 3.0°C (5.4°F) above the values for the comfort zone without elevated air speed. The required air speed may not be higher than 0.8 m/s (160 fpm). Large individual differences exist between people with regard to the preferred air speed. Therefore, the elevated air speed must be under the direct control of the affected occupants and adjustable in steps no greater than 0.15 m/s (30 fpm). The benefits that can be gained by increasing air speed depend on clothing and activity. Due to increases in skin wettedness, the effect of increased speed is greater with elevated activity than with sedentary activity. Due to increased amounts of exposed skin, the effect of increased air speed is greater with lighter clothing. Thus, Figure 5.2.3 is conservative for activity levels above 1.3 met and/or for clothing insulation less than 0.5 clo and may be applied in these circumstances.

Due to increased body coverage, the effect of increased air speed is less with higher levels of clothing insulation. Thus, Figure 5.2.3 will underestimate the required air speed for clothing insulation greater than 0.7 clo and shall not be applied in these circumstances.

5.2.4 Local Thermal Discomfort. The local thermal discomfort caused by a vertical air temperature difference between the feet and the head by an asymmetric radiant field, by local convective cooling (draft), or by contact with a hot or cold floor must be considered in determining conditions for acceptable thermal comfort. Requirements for these factors are specified in this section.

TABLE 5.2.4
Percentage Dissatisfied Due to Local Discomfort from Draft (DR) or Other Sources (PD)

DR Due to Draft	PD Due to Vertical Air Temperature Difference	PD Due to Warm or Cool Floors	PD Due to Radiant Asymmetry
< 20%	< 5%	< 10%	< 5%

TABLE 5.2.4.1
Allowable Radiant Temperature Asymmetry

Radiant Temperature Asymmetry °C (°F)			
Warm Ceiling	**Cool Wall**	**Cool Ceiling**	**Warm Wall**
< 5 (9.0)	< 10 (18.0)	< 14 (25.2)	< 23 (41.4)

The requirements specified in this section apply to a lightly clothed person (with clothing insulation between 0.5 clo and 0.7 clo) engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met). With higher metabolic rates and/or with more clothing insulation, people are less thermally sensitive and, consequently, the risk of local discomfort is lower. Thus, the requirements of this section may also be used for metabolic rates greater than 1.3 met and with clothing insulation greater than 0.7 clo and will be conservative. People are more sensitive to local discomfort when the whole body is cooler than neutral and less sensitive to local discomfort when the whole body is warmer than neutral. The requirements of this section are based on environmental temperatures near the center of the comfort zone. These requirements apply to the entire comfort zone, but they may be conservative for conditions near the upper temperature limits of the comfort zone and may underestimate acceptability at the lower temperature limits of the comfort zone.

Table 5.2.4 specifies the expected percent dissatisfied (PD) for each source of local thermal discomfort described in Sections 5.2.4.1 through 5.2.4.4. The criteria for all sources of local thermal discomfort must be met simultaneously at the levels specified for an environment to meet the requirements of this standard.

5.2.4.1 Radiant Temperature Asymmetry. The thermal radiation field about the body may be nonuniform due to hot and cold surfaces and direct sunlight. This asymmetry may cause local discomfort and reduce the thermal acceptability of the space. In general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by hot and cold vertical surfaces. Figure 5.2.4.1 gives the predicted percentage of dissatisfied occupants as a function of the radiant temperature asymmetry caused by a warm ceiling, a cool wall, a cool ceiling, or a warm wall.

The limits for radiant temperature asymmetry are specified in Table 5.2.4.1. Alternatively, Figure 5.4.2.1 may be used in conjunction with the PD limits from Table 5.2.4 to determine the allowable radiant asymmetry.

5.2.4.2 Draft. Draft is unwanted local cooling of the body caused by air movement. Draft sensation depends on the air speed, the air temperature, the turbulence intensity, the activity, and the clothing. Sensitivity to draft is greatest where the skin is not covered by clothing, especially the head region comprising the head, neck, and shoulders and the leg region

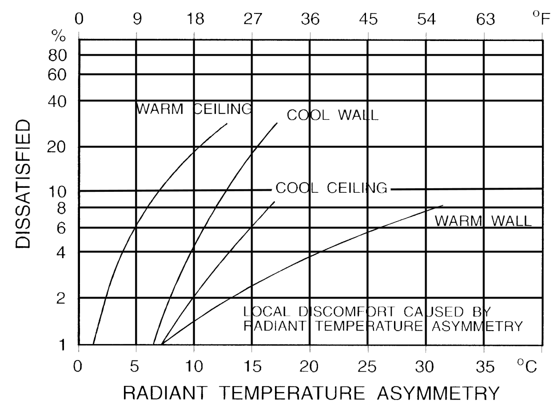

Figure 5.2.4.1 Local thermal discomfort caused by radiant asymmetry.

comprising the ankles, feet, and legs. The requirements in this section are based on sensitivity to draft in the head region with airflow from behind and may be conservative for some locations on the body and for some directions of airflow.

The maximum allowable air speed is specified in Figure 5.2.4.2 as a function of air temperature and turbulence intensity. Alternatively, the following equation may be used for determining the maximum allowable air speed. The predicted percentage of people dissatisfied due to annoyance by draft (DR) is given by

$$DR = ([34-t_a] * [v-0.05]^{0.62}) * (0.37 * v * Tu + 3.14)\ ,$$

where

DR = predicted percentage of people dissatisfied due to draft;
t_a = local air temperature, °C;
v = local mean air speed, m/s, based on v_a, the mean velocity; and
Tu = local turbulence intensity, %.

For t_a (°F), v in fpm, and Tu (%),

$$DR = ([93.2 - t_a] * [v - 10]^{0.62}) * (0.00004 * v * Tu + 0.066)\ .$$

For $v < 0.05$ m/s (10 fpm), use $v = 0.05$ m/s (10 fpm).
For DR > 100%, use DR = 100%.

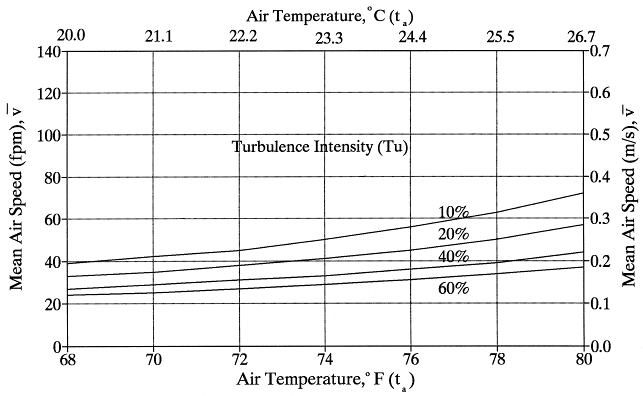

Figure 5.2.4.2 Allowable mean air speed as a function of air temperature and turbulence intensity.

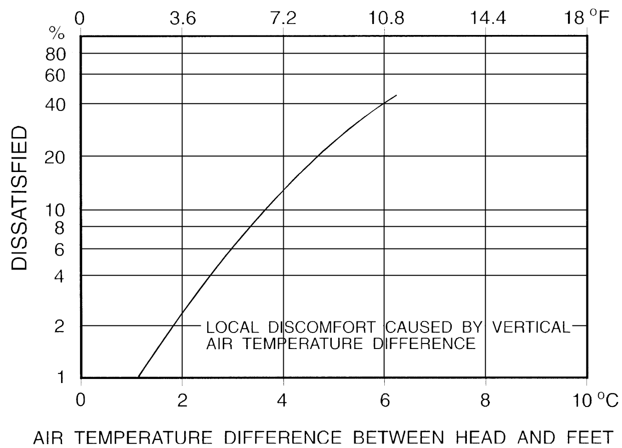

Figure 5.2.4.3 Local thermal discomfort caused by vertical temperature differences.

The values of DR predicted from this equation must be within the limits specified for draft in Table 5.2.4. On average, the turbulence intensity in a large part of the occupied zone of rooms with mixing ventilation is around 35%, and it is 20% in rooms with displacement ventilation or without mechanical ventilation. These values may be used in the above equation when the turbulence intensity is not measured.

The criteria specified in this section do not apply to the use of elevated air speed in Section 5.2.3. However, when occupants choose to turn off the elevated air speed, these criteria apply.

5.2.4.3 Vertical Air Temperature Difference. Thermal stratification that results in the air temperature at the head level being warmer than at the ankle level may cause thermal discomfort. This section specifies allowable differences between the air temperature at head level and the air temperature at ankle level. Figure 5.2.4.3 gives the predicted percentage of dissatisfied occupants as a function of the air temperature difference where the head level is warmer than the ankle level. Thermal stratification in the opposite direction is rare, is perceived more favorably by occupants, and is not addressed in this standard.

The allowable differences in air temperature from the ankle level to the head level may be determined from Table 5.2.4.3. Alternatively, Figure 5.2.4.3 may be used in conjunction with the PD limit for vertical temperature differences in Table 5.2.4 to determine the allowable differences in air temperature from the ankle level to the head level.

TABLE 5.2.4.3
Allowable Vertical Air Temperature Difference Between Head and Ankles

Vertical Air Temperature Difference °C (°F)
< 3 (< 5.4)

TABLE 5.2.4.4
Allowable Range of the Floor Temperature

Range of Surface Temperature of the Floor °C (°F)
19-29 (66.2-84.2)

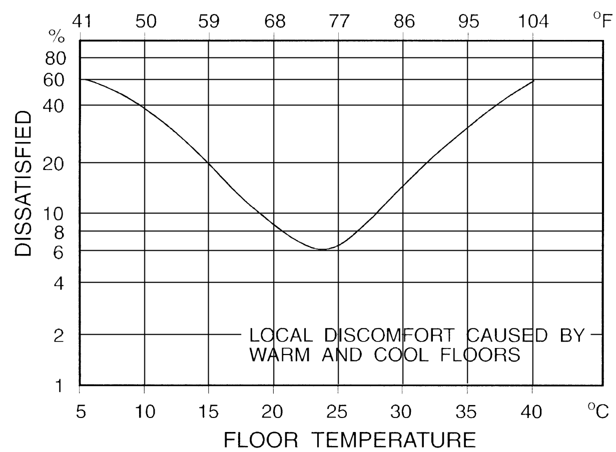

Figure 5.2.4.4 Local discomfort caused by warm and cool floors.

5.2.4.4 Floor Surface Temperature. Occupants may feel uncomfortable due to contact with floor surfaces that are too warm or too cool. The temperature of the floor, rather than the material of the floor covering, is the most important factor for foot thermal comfort for people wearing shoes. Figure 5.2.4.4 gives the predicted percentage of dissatisfied occupants as a function of floor temperature. The criteria in this section are based on people wearing lightweight indoor shoes. These criteria may also be used for people wearing heavier footgear, but may be conservative. This standard does not address the floor temperature required for people not wearing shoes. Nor does it address acceptable floor temperatures when people sit on the floor.

The limits for floor temperature are specified in Table 5.2.4.4. Alternatively, Figure 5.2.4.4 may be used in conjunction with the PD limit from Table 5.2.4 to determine the allowable floor temperature range.

5.2.5 Temperature Variations with Time. Fluctuations in the air temperature and/or mean radiant temperature may affect the thermal comfort of occupants. Those fluctuations under the direct control of the individual occupant do not have a negative impact on thermal comfort, and the requirements of this section do not apply to these fluctuations. Fluctuations that occur due to factors not under the direct control of the individual occupant (e.g., cycling from thermostatic control) may have a negative effect on comfort, and the requirements of this section do apply to these fluctuations. Fluctuations that occupants experience as a result of moving between locations with different environmental conditions are allowed as long as the conditions at all of these locations are within the comfort zone for these moving occupants.

5.2.5.1 Cyclic Variations. Cyclic variations refer to those situations where the operative temperature repeatedly rises and falls, and the period of these variations is not greater than 15 minutes. If the period of the fluctuation cycle exceeds 15 minutes, the variation is treated as a drift or ramp in operative temperature, and the requirements of Section 5.2.5.2 apply. In some situations, variations with a period not greater than 15 minutes are superimposed on variations with a longer period. In these situations, the requirements of Section 5.2.5.1 apply to the component of the variation with a period not greater than 15 minutes, and the requirements of Section 5.2.5.2 apply to the component of the variation with a period greater than 15 minutes.

Table 5.2.5.1 specifies the maximum allowable peak-to-peak cyclic variation in operative temperature.

5.2.5.2 Drifts or Ramps. Temperature drifts and ramps are monotonic, noncyclic changes in operative temperature. The requirements of this section also apply to cyclic variations with a period greater than 15 minutes. Generally, drifts refer to passive temperature changes of the enclosed space, and ramps refer to actively controlled temperature changes. The requirements of this section are the same for drifts and ramps.

Table 5.2.5.2 specifies the maximum change in operative temperature allowed during a period of time. For any given time period, the most restrictive requirements from Table 5.2.5.2 apply. For example, the operative temperature may not change more than 2.2°C (4.0°F) during a 1.0-h period, and it also may not change more than 1.1°C (2.0°F) during any 0.25-h period within that 1.0-h period. If variations are created as a result of control or adjustments by the user, higher values may be acceptable.

5.3 Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces

For the purposes of this standard, occupant-controlled naturally conditioned spaces are those spaces where the thermal conditions of the space are regulated primarily by the occupants through opening and closing of windows. Field experiments have shown that occupants' thermal responses in such spaces depend in part on the outdoor climate and may differ from thermal responses in buildings with centralized HVAC systems primarily because of the different thermal experiences, changes in clothing, availability of control, and shifts in occupant expectations. This optional method is intended for such spaces.

In order for this optional method to apply, the space in question must be equipped with operable windows that open to the outdoors and that can be readily opened and adjusted by the occupants of the space. There must be no mechanical cooling system for the space (e.g., refrigerated air conditioning, radiant cooling, or desiccant cooling). Mechanical ventilation with unconditioned air may be utilized, but opening and closing of windows must be the primary means of regulating the thermal conditions in the space. The space may be provided with a heating system, but this optional method does not apply when the heating system is in operation. It applies only to spaces where the occupants are engaged in near sedentary physical activities, with metabolic rates ranging from 1.0 met to 1.3 met. See Appendix A for estimation of metabolic rates. This optional method applies only to spaces where the occupants may freely adapt their clothing to the indoor and/or outdoor thermal conditions.

Allowable indoor operative temperatures for spaces that meet these criteria may be determined from Figure 5.3. This figure includes two sets of operative temperature limits—one for 80% acceptability and one for 90% acceptability. The 80% acceptability limits are for typical applications and shall be used when other information is not available. The 90% acceptability limits may be used when a higher standard of thermal comfort is desired. Figure 5.3 is based on an adaptive model of thermal comfort that is derived from a global database of 21,000 measurements taken primarily in office buildings.

The allowable operative temperature limits in Figure 5.3 may not be extrapolated to outdoor temperatures above and below the end points of the curves in this figure. If the mean monthly outdoor temperature is less than 10°C (50°F) or greater than 33.5°C (92.3°F), this option may not be used, and no specific guidance for naturally conditioned spaces is included in this standard.

TABLE 5.2.5.1
Allowable Cyclic Operative Temperature Variation

Allowable Peak-to-Peak Variation in Operative Temperature, °C (°F)
1.1 (2.0)

TABLE 5.2.5.2
Limits on Temperature Drifts and Ramps

Time Period	0.25 h	0.5 h	1 h	2 h	4 h
Maximum Operative Temperature Change Allowed	1.1°C (2.0°F)	1.7°C (3.0°F)	2.2°C (4.0°F)	2.8°C (5.0°F)	3.3°C (6.0°F)

Plaintiffs' MSJ Appx. 2554

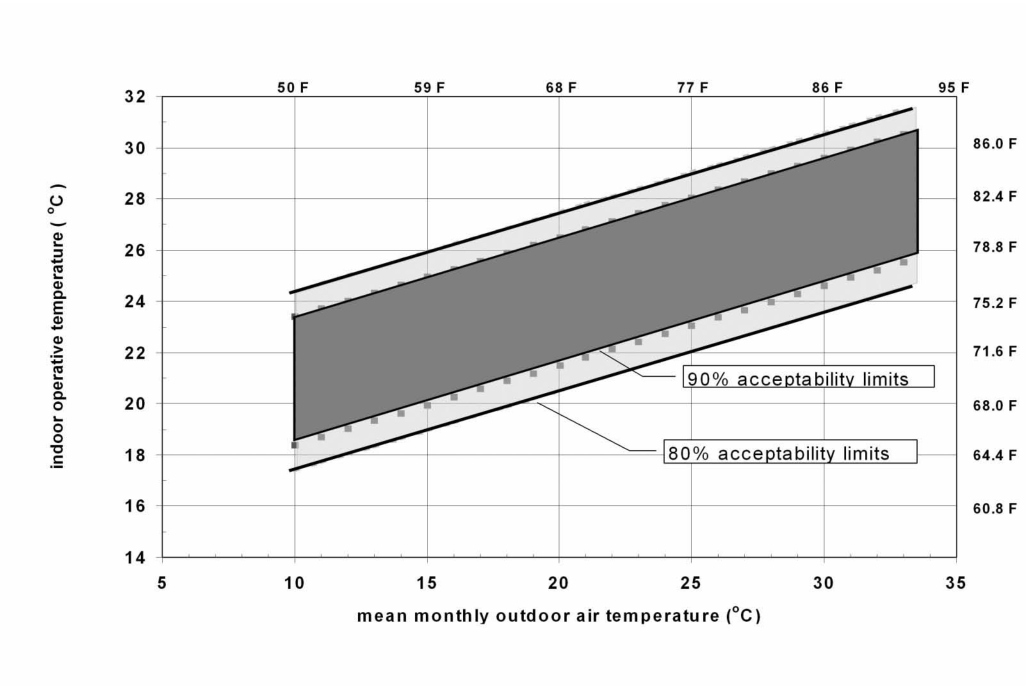

Figure 5.3 Acceptable operative temperature ranges for naturally conditioned spaces.

Figure 5.3 accounts for local thermal discomfort effects in typical buildings, so it is not necessary to address these factors when using this option. However, if there is reason to believe that local thermal discomfort is a problem, the criteria in Section 5.2.4 may be applied.

Figure 5.3 also accounts for people's clothing adaptation in naturally conditioned spaces by relating the acceptable range of indoor temperatures to the outdoor climate, so it is not necessary to estimate the clothing values for the space.

No humidity or air speed limits are required when this option is used.

5.4 Description of Thermal Environmental Variables

The following description of the environmental variables is provided for the purpose of understanding their use in Section 5. It is not intended to be a measurement specification. Section 7 specifies measurement requirements. If there is a discrepancy between the descriptions in this section and the requirements in Section 7, then the requirements in Section 7 supersede the descriptions in this section for the purpose of measurement.

For the purposes of Section 5, the thermal environment is defined with respect to the occupant.

Air temperature is the average temperature of the air surrounding an occupant. The average is with respect to location and time. As a minimum, the spatial average is the numerical average of the air temperature at the ankle level, the waist level, and the head level. These levels are 0.1, 0.6, and 1.1 m (4, 24, and 43 in.), respectively, for seated occupants, and 0.1, 1.1, and 1.7 m (4, 43, and 67 in.) for standing occupants. Intermediate, equally spaced locations may also be included in the average. When the occupant is located in a directed airflow, the air temperature on the upstream side shall be used. As a minimum, the temporal average is a three-minute average with at least 18 equally spaced points in time. However, the period may extend up to 15 minutes to average cyclic fluctuations if necessary. The temporal average applies to all locations in the spatial average.

Local air temperature is defined in the same way as the air temperature except that it refers to a single level (e.g., head level). At least one location is required at this level. However, multiple locations around the body may be included to determine a better average.

Mean radiant temperature is defined as the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure. It is a single value for the entire body and may be considered a spatial average of the temperature of surfaces surrounding the occupant weighted by their view factors with respect to the occupant. See Chapter 8 in the *2001 ASHRAE Handbook—Fundamentals*[3] for a more complete description of mean radiant temperature. For the purposes of Section 5, mean radiant temperature is also a time-averaged value. As a minimum, the temporal average is a three-minute average with at least 18 equally spaced points in time. However, the period may extend up to 15 minutes to average cyclic fluctuations if necessary.

Operative temperature is the average of the air temperature and the mean radiant temperature weighted, respectively, by the convective heat transfer coefficient and the linearized radiant heat transfer coefficient for the occupant. See Chapter 8 in the *2001 ASHRAE Handbook—Fundamentals*[3] for a more complete description of operative temperature. For occupants engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s (40 fpm), the relationship can be approximated with acceptable accuracy by

$$t_o = (t_a + t_r) / 2 \,,$$

Plaintiffs' MSJ Appx. 2555

where

t_o = operative temperature,
t_a = air temperature, and
t_r = mean radiant temperature.

Radiant asymmetry is the difference between the plane radiant temperature in opposite directions. The plane radiant temperature is defined similarly to mean radiant temperature except that it is with respect to a small planar surface element exposed to the thermal radiation from surfaces from one side of that plane. The vertical radiant asymmetry is with plane radiant temperatures in the upward and downward direction. The horizontal radiant asymmetry is the maximum difference between opposite plane radiant temperatures for all horizontal directions. The radiant asymmetry is determined at waist level—0.6 m (24 in.) for a seated occupant and 1.1 m (43 in.) for a standing occupant. Time averaging for radiant asymmetry is the same as for mean radiant temperature. See Chapter 8 in the *2001 ASHRAE Handbook—Fundamentals*[3] for a more complete description of plane radiant temperature and radiant asymmetry.

Floor temperature (t_f) is the surface temperature of the floor when it is in contact with the occupants' shoes. Since floor temperatures seldom change rapidly, time averaging does not need to be considered.

Mean monthly outdoor temperature is the arithmetic average of the mean daily minimum and mean daily maximum outdoor (dry-bulb) temperature for the month in question.

Air speed is the average speed of the air to which the body is exposed. The average is with respect to location and time. Time averaging and spatial averaging are the same as for air temperature. However, the time-averaging period extends only to three minutes. Variations that occur over a period greater than three minutes shall be treated as multiple different air speeds.

Turbulence intensity is the ratio of the standard deviation of the air speed with respect to time and the time-averaged air speed. The turbulence intensity is primarily for the head/shoulder portions of the body—the 1.1 m (43 in.) level for seated occupants and the 1.7 m (67 in.) level for standing occupants. It may also apply to the ankle/lower leg areas if they are not covered with clothing—the 0.1 m (4 in.) level for both standing and seated occupants.

Humidity is a general reference to the moisture content of the air. It may be expressed in terms of several thermodynamic variables, including vapor pressure, dew-point temperature, and humidity ratio. It is spatially and temporally averaged in the same manner as air temperature.

6. COMPLIANCE

6.1 Design

The scope of this standard does not include specific guidance regarding mechanical systems, control systems, or the thermal envelopes for spaces. Building systems (combinations of mechanical systems, control systems, and thermal envelopes) shall be designed so that, at design conditions, they are able to maintain the space at conditions within the range specified by one of the methods in this standard. Additionally, the mechanical systems, control systems, and thermal envelopes shall be designed so that they are able to maintain the space at conditions within the range specified in this standard at all combinations of less extreme conditions that are expected to occur. The less extreme conditions can include both internal loads and the external environment. The system shall have controls that enable it to meet comfort requirements at less than full system capacity.

The method and design conditions, including the design exceedance level, appropriate for the intended use of the building shall be selected and should be documented in accordance with Section 6.1.1.

Design weather data are statistically based and established to explicitly acknowledge certain percentages of exceedance (e.g., 1% design, 4 month summer basis, 29 hours of exceedance). This recognizes the impracticality of providing an HVAC system that can meet all loads under all weather or operating conditions encountered in its lifetime. Thus, in practice, the requirements of Section 5 may not be met during excursions from the design conditions. Also, weather-based exceedance will usually be less than indicated by the exceedance percentage because other design loads will seldom be concurrent.

Because of differences in metabolic rates between individuals and the resultant differences in response to the environment, actual operating building temperatures cannot be specified in this standard.

6.1.1 Documentation. Complete plans, descriptions, component literature, and operation and maintenance instructions for the building systems should be provided and maintained. These should include, but not be limited to, building system design specifications and design intent as follows.

Note: Some of the sections below may not be applicable to naturally conditioned buildings.

1. The design criteria of the system in terms of indoor temperature and humidity, including any tolerance or range, based on stated design outdoor ambient conditions and total indoor loads, should be stated. Values assumed for comfort parameters used in calculation of design temperatures, including clothing and metabolic rate, should be clearly stated.
2. The system input or output capacities necessary to attain the design indoor conditions at design outdoor ambient conditions should be stated, as well as the full input or output capacities of the system as supplied and installed.
3. The limitations of the system to control the environment of the zone(s) should be stated whether based on temperature, humidity, ventilation, time of week, time of day, or seasonal criteria.
4. The overall space supplied by the system should be shown in a plan view layout, with all individual zones within it identified. All registers or terminal units should be shown and identified with type and flow or radiant value.
5. Significant structural and decor items should be shown and identified if they affect indoor comfort. Notes should be provided to identify which areas within a space and which locations relative to registers, terminal units, relief grilles,

and control sensors should not be obstructed in order to avoid negatively affecting indoor comfort.

6. Areas within any zone that lie outside the comfort control areas, where people should not be permanently located, should be identified.
7. Locations of all occupant adjustable controls should be identified, and each should be provided with a legend describing which zone(s) it controls, which function(s) it controls, how it is to be adjusted, the range of effect it can have, and the recommended setting for various times of day, season, or occupancy load.
8. A block-diagram control schematic should be provided with sensors, adjustable controls, and actuators accurately identified for each zone. If zone control systems are independent but identical, one diagram is sufficient if identified for which zones it applies. If zones are interdependent or interactive, their control diagram should be shown in total on one block diagram with the point(s) of interconnection identified.
9. The general maintenance, operation, and performance of the building systems should be stated, followed by more specific comments on the maintenance and operation of the automatic controls and manually adjustable controls and the response of the system to each. Where necessary, specific seasonal settings of manual controls should be stated, and major system changeovers that are required to be performed by a professional service agency should be identified.
10. Specific limits in the adjustment of manual controls should be stated. Recommendations for seasonal settings on these controls should be stated, along with the degree of manual change that should be made at any one time, and the waiting time between adjustments when trying to fine-tune the system. A maintenance and inspection schedule for all thermal environmental-related building systems should be provided.
11. Assumed electrical load for lighting and equipment in occupied spaces (including diversity considerations) used in HVAC load calculations should be documented, along with any other significant thermal and moisture loads assumed in HVAC load calculations and any other assumptions upon which HVAC and control design is based.

6.2 Validation

Validation should be performed as described in Section 7 to demonstrate that the building systems can be operated to meet the requirements of Section 5 according to the design intent and under design conditions inclusive of less severe conditions, as documented in Section 6.1.1.

7. EVALUATION OF THE THERMAL ENVIRONMENT

At the design stage, the thermal environment may be evaluated by calculations. Simple hand calculations and computer models of buildings and systems are available for this purpose. Use this section to evaluate existing thermal environments with respect to this standard. Full-scale laboratory testing may provide a more controlled validation, however.

7.1 Measuring Device Criteria

The measuring instrumentation used shall meet the requirements for measuring range and accuracy given in ASHRAE Standard 70-1991[5] or 113-1990[6] or in ISO 7726,[1] and the referenced source shall be so identified.

7.2 Measurement Positions

7.2.1 Location of Measurements. Measurements shall be made in occupied zones of the building at locations where the occupants are known to or are expected to spend their time.

Such locations might be workstation or seating areas, depending on the function of the space. In occupied rooms, measurements shall be taken at a representative sample of occupant locations spread throughout the occupied zone. In unoccupied rooms, the evaluator shall make a good faith estimate of the most significant future occupant locations within the room and make appropriate measurements.

If occupancy distribution cannot be estimated, then the measurement locations shall be as follows:

(a) In the center of the room or zone.
(b) 1.0 m (3.3 ft) inward from the center of each of the room's walls. In the case of exterior walls with windows, the measurement location shall be 1.0 m (3.3 ft) inward from the center of the largest window.

In either case, measurements shall be taken in locations where the most extreme values of the thermal parameters are estimated or observed to occur. Typical examples might be near windows, diffuser outlets, corners, and entries. Measurements are to be made sufficiently away from the boundaries of the occupied zone and from any surfaces to allow for proper circulation around measurement sensors with positions as described below.

Absolute humidity need be determined at only one location within the occupied zone in each occupied room or HVAC-controlled zone, provided it can be demonstrated that there is no reason to expect large humidity variations within that space. Otherwise, absolute humidity shall be measured at all locations defined above.

7.2.2 Height Above Floor of Measurements. Air temperature and air speed shall be measured at the 0.1, 0.6, and 1.1 m (4, 24, and 43 in.) levels for sedentary occupants at the locations specified in Section 7.2.1. Standing activity measurements shall be made at the 0.1, 1.1, and 1.7 m (4, 43, and 67 in.) levels. Operative temperature or PMV-PPD shall be measured or calculated at the 0.6 m (24 in.) level for seated occupants and the 1.1 m (43 in.) level for standing occupants.

Radiant asymmetry shall be measured at the 0.6 m (24 in.) level for seated occupants and the 1.1 m (43 in.) for standing occupants. If desk-level furniture (that is in place) blocks the view of strong radiant sources and sinks, the measurements are to be taken above desktop level. Floor surface temperatures are to be measured with the anticipated floor coverings installed. Humidity shall be measured at any level within the occupied zone if only one measurement location is required. Otherwise

it shall be measured at the 0.6 m (24 in.) level for seated occupants and the 1.1 m (43 in.) level for standing occupants.

7.3 Measurement Periods

7.3.1 Air Speed. The measuring period for determining the average air speed at any location shall be three minutes. Turbulence intensity is measured in the same period by calculating the ratio of the standard deviation for the period to the average air speed. (See Section 3 for the definition of response time and its relation to the time constant.)

7.3.2 Temperature Cycles and Drifts. For determining compliance with the non-steady-state requirements of Section 5, the rate of change of operative temperature is used. It is the difference between maximum and minimum operative temperatures measured during the same cycle, divided by the elapsed time in minutes.

$$\text{Rate of change (degrees/h)} = 60\ (t_{o,\,max} - t_{o,\,min})\ /\ \text{time (minutes)}$$

The measurements shall be made every five minutes or less for at least two hours to establish the nature of the temperature cycle. The use of an automatic recorder is the preferred method of measurement; however, it is possible to make the measurements required in this section without the use of recording equipment.

7.3.3 Clothing and Activity. In buildings, it may be appropriate to measure the clothing and activity levels of the occupants. These shall be estimated in the form of mean values over a period of 0.5 to 1.0 hour immediately prior to measuring the thermal parameters.

7.4 Measuring Conditions

In order to determine the effectiveness of the building system at providing the environmental conditions specified in this standard, measurements shall be made under the following conditions.

To test during the heating period (winter conditions), the measurements required shall be made when the indoor-outdoor temperature difference is not less than 50% of the difference used for design and with cloudy to partly cloudy sky conditions. If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions are acceptable.

To test during the cooling period (summer conditions), the measurements required shall be made when the outdoor-indoor temperature difference and humidity difference are not less than 50% of the differences used for design and with clear to partly cloudy sky conditions. If these sky conditions are rare and not representative of the sky conditions used for design, then sky conditions representative of design conditions are acceptable.

To test interior zones of large buildings, the measurements required shall be made with the zone loaded to at least 50% of the design load for at least one complete cycle of the HVAC system, if the system is not proportionally controlled. Simulation of heat generated by occupants is recommended.

7.5 Mechanical Equipment Operating Conditions

In order to determine appropriate corrective actions following the use of this standard to analyze the environment, the following operations of the mechanical system shall be measured concurrently with the environmental data:

- Air supply rate into the space being measured
- Room/supply air temperature differential
- Type and location of room diffuser or air outlet
- Discharge air speed
- Perimeter heat type, location, and status
- Return grille location and size
- Type of air supply system
- Surface temperatures of heated or cooled surfaces
- Water supply and return temperatures of hydronic systems

7.6 Validating the Thermal Environment for New Buildings and Installations

7.6.1 Define Criteria. Before validating a thermal environment that meets the requirements of this standard, the original design conditions specified shall be defined. From this definition, the validation team will evaluate the system's ability to meet and maintain the desired comfort level(s). The comfort criteria definition shall include, but not be limited to, the following:

- Temperature (air, radiant, surface)
- Humidity
- Air speed

The environmental conditions that were originally specified shall be defined as well to ensure that measurements taken correspond correctly to the design parameters. Environmental conditions shall include, but again are not limited to, the following:

- Outdoor temperature design conditions
- Outdoor humidity design conditions
- Clothing (seasonal)
- Activity expected

7.6.2 Select Validation Method. In order to determine the thermal environment's ability to meet the defined criteria as outlined in Section 7.6.1 above, there are two methods (one described in Section 7.6.2.1 and the other in Section 7.6.2.2) that can be implemented. The first method of validating the thermal environment is to statistically determine occupant satisfaction through the evaluation of survey results. The second is to technically establish comfort conditions through the analysis of environment variables.

7.6.2.1 Survey Occupants. The purpose of this standard is to ensure that a room, building, etc., is comfortable for a substantial majority (at least 80%) of the occupants. Therefore, an effective way to evaluate the environmental conditions is to survey the occupants. This survey should be performed for every operating mode, in every design condition. This would require a survey check sheet to be provided by the team responsible for validating the thermal environment of the space. The sheet shall have, as a minimum, the following data for the occupant to fill in:

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- Occupant's name, date, and time
- Approximate outside air temperature
- Clear sky/overcast (if applicable)
- Seasonal conditions
- Occupant's clothing
- Occupant's activity level
- Applicable equipment
- General thermal comfort level
- Occupant's location

In addition to the occupant's data, space shall be provided for the surveyor to number the survey, summarize the results, and sign his/her name. A sample check sheet and clothing table are provided in Appendix E.

7.6.2.2 Analyze Environment Variables. The second method for evaluating the comfort conditions is to analyze specific environmental data for compliance with the requirements of this standard. Each application of validating the thermal environment is unique. A specific test plan will be required to accommodate the project scope.

Assess the environment for which comfort conditions are going to be verified. Determine the need to verify floor surface temperature, vertical temperature difference, and radiant temperature asymmetry. When this need exists, it is important to ensure the maximum potential for variance is exploited (e.g., take radiant asymmetry temperature reading on a sunny day with the blinds open).

Under all expected operating conditions, air speed (nondirectional), air temperature, and humidity shall be verified.

- Verify satisfactory air speed with a group of readings taken at a strategic location within the space. For VAV systems, readings shall be taken at maximum flow with minimum supply air temperature.
- Determine the best location for providing accurate air temperature and humidity readings. Proof of performance for both air temperature and humidity shall require trended data.

Where variables are going to be trended, successful comfort control shall be a function of steady-state performance. Steady state shall require that the trended variable remain within a specified range without cycling. Cycling is defined as fluctuation over 50% of the permitted range every 15 minutes or more frequently. This verification shall include trending variables for at least one occupied cycle during each seasonal condition. When thermal conditions in the occupied zone have a high sensitivity to time of day and weather conditions, the measurement shall be made such that the high and low extremes of the thermal parameters are determined. ASHRAE Standard 113-1990[6] offers a procedure for determining air speed and temperature variations in building spaces and provides additional guidance for the measurement of mechanical equipment parameters.

7.6.3 Provide Documentation. The effort of validation also involves ensuring a thoroughly documented process. Whichever method of validating the thermal environment is chosen, the process shall be well documented.

7.6.3.1 Documenting Surveys. When the occupants of a building are surveyed as outlined in Section 7.6.2.1, the survey method shall be developed, written, and turned over, with the sample survey sheets, to the appropriate parties for review and approval.

7.6.3.2 Documenting Variable Analysis. For analysis of the environmental variables outlined in Section 7.6.2, the trend logs and data analysis shall be prepared. Again, the method of trending must be included with this submission, if it has not been provided prior to validation, for approval.

8. REFERENCES

1. *ISO 7726:1998, Ergonomics of the thermal environment--Instruments for measuring physical quantities.*
2. *ISO 7730:1994, Moderate thermal environments--Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.*
3. *2001 ASHRAE Handbook—Fundamentals.*
4. *ASHRAE Thermal Comfort Tool CD* (ASHRAE Item Code 94030).
5. *ASHRAE Standard 70-1991, Method of Testing for Rating the Performance of Air Outlets and Inlets.*
6. *ASHRAE Standard 113-1990, Method of Testing for Room Air Diffusion.*

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A—ACTIVITY LEVELS

Metabolic Rates for Typical Tasks

Activity	Met Units	Metabolic Rate W/m^2	(Btu/h·ft^2)
Resting			
Sleeping	0.7	40	(13)
Reclining	0.8	45	(15)
Seated, quiet	1.0	60	(18)
Standing, relaxed	1.2	70	(22)
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	(37)
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	(48)
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	(70)
Office Activities			
Seated, reading, or writing	1.0	60	(18)
Typing	1.1	65	(20)
Filing, seated	1.2	70	(22)
Filing, standing	1.4	80	(26)
Walking about	1.7	100	(31)
Lifting/packing	2.1	120	(39)
Driving/Flying			
Automobile	1.0-2.0	60-115	(18-37)
Aircraft, routine	1.2	70	(22)
Aircraft, instrument landing	1.8	105	(33)
Aircraft, combat	2.4	140	(44)
Heavy vehicle	3.2	185	(59)
Miscellaneous Occupational Activities			
Cooking	1.6-2.0	95-115	(29-37)
House cleaning	2.0-3.4	115-200	(37-63)
Seated, heavy limb movement	2.2	130	(41)
Machine work			
sawing (table saw)	1.8	105	(33)
light (electrical industry)	2.0-2.4	115-140	(37-44)
heavy	4.0	235	(74)
Handling 50 kg (100 lb) bags	4.0	235	(74)
Pick and shovel work	4.0-4.8	235-280	(74-88)
Miscellaneous Leisure Activities			
Dancing, social	2.4-4.4	140-255	(44-81)
Calisthenics/exercise	3.0-4.0	175-235	(55-74)
Tennis, single	3.6-4.0	210-270	(66-74)
Basketball	5.0-7.6	290-440	(92-140)
Wrestling, competitive	7.0-8.7	410-505	(129-160)

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Use of Metabolic Rate Data

These data are reproduced from Chapter 8 of the *2001 ASHRAE Handbook—Fundamentals*. The values in the table represent typical metabolic rates per unit of skin surface area for an average adult (DuBois area = 1.8 m^2, or 19.6 ft^2) for activities performed continuously. This handbook chapter provides additional information for estimating and measuring activity levels. General guidelines for the use of these data follow.

Every activity that may be of interest is not included in this table. Users of this standard should use their judgment to match the activities being considered to comparable activities in the table. Some of the data in this table are reported as a range, and some as a single value. The format for a given entry is based on the original data source and is *not* an indication of when a range of values should or should not be utilized. For all activities except sedentary activities, the metabolic rate for a given activity is likely to have a substantial range of variation that depends on the individual performing the task and the circumstances under which the task is performed.

A time-weighted average metabolic rate may be used for individuals with activities that vary over a period of one hour or less. For example, a person who typically spends 30 minutes out of each hour "lifting/packing," 15 minutes "filing, standing," and 15 minutes "walking about" has an average metabolic rate of $0.50 \times 2.1 + 0.25 \times 1.4 + 0.25 \times 1.7 = 1.8$ met. Such averaging should not be applied when the period of variation is greater than one hour. For example, a person who is engaged in "lifting/packing" for one hour and then "filing, standing" the next hour should be treated as having two distinct metabolic rates.

As metabolic rates increase above 1.0 met, the evaporation of sweat becomes an increasingly important factor for thermal comfort. The PMV method does not fully account for this factor, and this standard should not be applied to situations where the time-averaged metabolic rate is above 2.0 met. Typically, rest breaks (scheduled or hidden) or other operational factors (get parts, move products, etc.) combine to limit time-weighted metabolic rates to about 2.0 met in most applications.

Time averaging of metabolic rates only applies to an individual. The metabolic rates associated with the activities of various individuals in a space may *not* be averaged to find a single, average metabolic rate to be applied to that space. The range of activities of different individuals in the space, and the environmental conditions required for those activities, should be considered in applying this standard. For example, the customers in a restaurant may have a metabolic rate near 1.0 met, while the servers may have metabolic rate closer to 2.0 met. Each of these groups of occupants should be considered separately in determining the conditions required for comfort. In some situations, it will not be possible to provide an acceptable level or the same level of comfort to all disparate groups of occupants (e.g., restaurant customers and servers).

The metabolic rates in this table were determined when the subjects' thermal sensation was close to neutral. It is not yet known the extent to which people may modify their metabolic rate to decrease warm discomfort.

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX B— CLOTHING INSULATION

The amount of thermal insulation worn by a person has a substantial impact on thermal comfort and is an important variable in applying this standard. Clothing insulation is expressed in a number of ways. In this standard, the clothing insulation of an ensemble expressed as a clo-value (I_{cl}) is used. Users not familiar with clothing insulation terminology are referred to Chapter 8, *2001 ASHRAE Handbook—Fundamentals,* for more information.

The insulation provided by clothing can be determined by a variety of means and, if accurate data are available from other sources, such as measurement with thermal manikins, these data may be used. When such information is not available, the tables in this appendix may be used to estimate clothing insulation using one of the methods described below. Regardless of the source of the clothing insulation value, this standard shall not be used with clothing ensembles with more than 1.5 clo of insulation. Also, this standard should not be used with clothing that is highly impermeable to moisture transport (e.g., chemical protective clothing or rain gear).

Three methods for estimating clothing insulation are presented. The methods are listed in order of accuracy and should be used in this order of preference.

- **Method 1:** Table B1 lists the insulation provided by a variety of common clothing ensembles. If the ensemble in question matches reasonably well with one of the ensembles in this table, then the indicated value of I_{cl} should be used.
- **Method 2:** Table B2 presents the thermal insulation of a variety of individual garments. These garments may be added to or subtracted from the ensembles in Table B1 to estimate the insulation of ensembles that differ in garment composition from those in Table B1. For example, if long underwear bottoms are added to Ensemble 5 in Table B1, the insulation of the resulting ensemble is estimated as I_{cl} = 1.01 clo + 0.15 clo = 1.16 clo.
- **Method 3:** A complete clothing ensemble may be defined using a combination of the garments listed in Table B2. The insulation of the ensemble is estimated as the sum of the individual values listed in Table B2. For example, the estimated insulation of an ensemble consisting of overalls worn with a flannel shirt, T-shirt, briefs, boots, and calf-length socks is I_{cl} = 0.30 + 0.34 + 0.08 + 0.04 + 0.10 + 0.03 = 0.89 clo.

Tables B1 and B2 are for a standing person. A sitting posture results in a decreased thermal insulation due to compression of air layers in the clothing. This decrease may be offset by insulation provided by the chair. Table B3 shows the net effect on clothing insulation for typical indoor clothing ensembles that results from sitting in a chair. These data may be used to adjust clothing insulation calculated using any of the above methods. For example, the clothing insulation for a person wearing Ensemble 3 from Table B1 and sitting in an

executive chair is 0.96 clo + 0.15 clo = 1.11 clo. For many chairs, the net effect of sitting is a minimal change in clothing insulation. For this reason, it is recommended that no adjustment be made to clothing insulation if there is uncertainty as to the type of chair and/or if the activity for an individual includes both sitting and standing.

Tables B1 and B2 are for a person that is not moving. Body motion decreases the insulation of a clothing ensemble by pumping air through clothing openings and/or causing air motion within the clothing. This effect varies considerably depending on the nature of the motion (e.g., walking versus lifting) and the nature of the clothing (stretchable and snug fitting versus stiff and loose fitting). Because of this variability, accurate estimates of clothing insulation for an active person are not available unless measurements are made for the specific clothing under the conditions in question (e.g., with a walking manikin). A rough estimate of the clothing insulation for an active person is

$$I_{cl,\ active} = I_{cl} \times (0.6 + 0.4 / M) \qquad 1.2 \text{ met} < M < 2.0 \text{ met}$$

where M is the metabolic rate in met units and I_{cl} is the insulation without activity. For metabolic rates less than or equal to 1.2 met, no adjustment is recommended.

When a person is sleeping or resting in a reclining posture, the bed and bedding may provide considerable thermal insulation. It is not possible to determine the thermal insulation for most sleeping or resting situations unless the individual is immobile. Individuals will adjust the bedding to suit individual preferences. Provided adequate bedding materials are available, the thermal environmental conditions desired for sleeping and resting vary considerably from person to person and cannot be determined by the methods included in this standard.

Clothing variability among occupants in a space is an important consideration in applying this standard. This variability takes two forms. In the first form, different individuals wear different clothing due to factors unrelated to the thermal conditions. Examples include different clothing style preferences for men and women and offices where managers are expected to wear suits while other staff members may work in shirtsleeves. In the second form, the variability results from adaptation to individual differences in response to the thermal environment. For example, some individuals may wear sweaters, while others wear short-sleeve shirts in the same environment if there are no constraints limiting what is worn. The first form of variability may result in differences in the requirements for thermal comfort between the different occupants, and these differences should be addressed in applying this standard. In this situation, it is *not* acceptable to determine the average clothing insulation of various groups of occupants to determine the thermal environmental conditions needed for all occupants. Each group must be considered separately. Where the variability within a group of occupants is of the second form and is a result only of individuals freely making adjustments in clothing to suit their individual thermal preferences, it is acceptable to use a single representative average clothing insulation value for everyone in that group.

For near sedentary activities where the metabolic rate is approximately 1.2 met, the effect of changing clothing insulation on the optimum operative temperature is approximately 6°C (11°F) per clo. For example, Table B2 indicates that adding a thin, long-sleeve sweater to a clothing ensemble increases clothing insulation by approximately 0.25 clo. Adding this insulation would lower the optimum operative temperature by approximately 6°C/clo × 0.25 clo = 1.5°C (11°F/clo × 0.25 clo = 2.8°F). The effect is greater with higher metabolic rates.

TABLE B1

Clothing Insulation Values for Typical Ensembles[a]

Clothing Description	Garments Included[b]	I_{cl} (clo)
Trousers	1) Trousers, short-sleeve shirt	0.57
	2) Trousers, long-sleeve shirt	0.61
	3) #2 plus suit jacket	0.96
	4) #2 plus suit jacket, vest, T-shirt	1.14
	5) #2 plus long-sleeve sweater, T-shirt	1.01
	6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	0.54
	8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	1.04
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10
Shorts	12) Walking shorts, short-sleeve shirt	0.36
Overalls/Coveralls	13) Long-sleeve coveralls, T-shirt	0.72
	14) Overalls, long-sleeve shirt, T-shirt	0.89
	15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	1.37
Athletic	16) Sweat pants, long-sleeve sweatshirt	0.74
Sleepwear	17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	0.96

a Data are from Chapter 8 in the *2001 ASHRAE Handbook—Fundamentals*.

b All clothing ensembles, except where otherwise indicated in parentheses, include shoes, socks, and briefs or panties. All skirt/dress clothing ensembles include pantyhose and no additional socks.

TABLE B2
Garment Insulation[a]

Garment Description[b]	I_{clu} (clo)	Garment Description[b]	I_{clu} (clo)
Underwear		**Dress and Skirts[c]**	
Bra	0.01	Skirt (thin)	0.14
Panties	0.03	Skirt (thick)	0.23
Men's briefs	0.04	Sleeveless, scoop neck (thin)	0.23
T-shirt	0.08	Sleeveless, scoop neck (thick), i.e., jumper	0.27
Half-slip	0.14	Short-sleeve shirtdress (thin)	0.29
Long underwear bottoms	0.15	Long-sleeve shirtdress (thin)	0.33
Full slip	0.16	Long-sleeve shirtdress (thick)	0.47
Long underwear top	0.20	**Sweaters**	
Footwear		Sleeveless vest (thin)	0.13
Ankle-length athletic socks	0.02	Sleeveless vest (thick)	0.22
Pantyhose/stockings	0.02	Long-sleeve (thin)	0.25
Sandals/thongs	0.02	Long-sleeve (thick)	0.36
Shoes	0.02	**Suit Jackets and Vests[d]**	
Slippers (quilted, pile lined)	0.03	Sleeveless vest (thin)	0.10
Calf-length socks	0.03	Sleeveless vest (thick)	0.17
Knee socks (thick)	0.06	Single-breasted (thin)	0.36
Boots	0.10	Single-breasted (thick)	0.42
Shirts and Blouses		Double-breasted (thin)	0.44
Sleeveless/scoop-neck blouse	0.13	Double-breasted (thick)	0.48
Short-sleeve knit sport shirt	0.17	**Sleepwear and Robes**	
Short-sleeve dress shirt	0.19	Sleeveless short gown (thin)	0.18
Long-sleeve dress shirt	0.25	Sleeveless long gown (thin)	0.20
Long-sleeve flannel shirt	0.34	Short-sleeve hospital gown	0.31
Long-sleeve sweatshirt	0.34	Short-sleeve short robe (thin)	0.34
Trousers and Coveralls		Short-sleeve pajamas (thin)	0.42
Short shorts	0.06	Long-sleeve long gown (thick)	0.46
Walking shorts	0.08	Long-sleeve short wrap robe (thick)	0.48
Straight trousers (thin)	0.15	Long-sleeve pajamas (thick)	0.57
Straight trousers (thick)	0.24	Long-sleeve long wrap robe (thick)	0.69
Sweatpants	0.28		
Overalls	0.30		
Coveralls	0.49		

a Data are from Chapter 8 in the *2001 ASHRAE Handbook—Fundamentals.*
b "Thin" refers to garments made of lightweight, thin fabrics often worn in the summer; "thick" refers to garments made of heavyweight, thick fabrics often worn in the winter.
c Knee-length dresses and skirts.
d Lined vests.

TABLE B3
Typical Added Insulation when Sitting on a Chair
(Valid for Clothing Ensembles with Standing Insulation Values of 0.5 clo < I_{cl} < 1.2 clo)

Net chair[a]	0.00 clo
Metal chair	0.00 clo
Wooden side arm chair[b]	0.00 clo
Wooden stool	+0.01 clo
Standard office chair	+0.10 clo
Executive chair	+0.15 clo

a A chair constructed from thin, widely spaced cords that provide no thermal insulation. Included for comparison purposes only.
b Chair used in most of the basic studies of thermal comfort that were used to establish the PMV-PPD index.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

INFORMATIVE APPENDIX C— ACCEPTABLE APPROXIMATION FOR OPERATIVE TEMPERATURE

The assumption that operative temperature equals air temperature is acceptable when these four conditions exist:

1. There is no radiant and/or radiant panel heating or radiant panel cooling system;
2. The average U-factor of the outside window/wall is determined by the following equation:

$$U_W < \frac{50}{t_{d,i} - t_{d,e}} \qquad \text{(SI)}$$

$$U_W < \frac{15.8}{t_{d,i} - t_{d,e}} \qquad \text{(IP)}$$

where

U_w = average U-factor of window/wall, $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$)
$t_{d,i}$ = internal design temperature, °C (°F)
$t_{d,e}$ = external design temperature, °C (°F);

3. Window solar heat gain coefficients (SHGC) are less than 0.48; and
4. There is no major heat generating equipment in the space.

Calculation of the Operative Temperature Based on Air and Mean-Radiant Temperature

In most practical cases where the relative air speed is small (< 0.2 m/s, 40 fpm) or where the difference between mean radiant and air temperature is small (< 4°C, 7°F), the operative temperature can be calculated with sufficient approximation as the mean value of air temperature and mean radiant temperature.

For higher precision and other environments, the following formula may be used:

$$t_{op} = A\, t_a + (1 - A)\, t_r$$

where

t_{op} = operative temperature,
t_a = air temperature,
t_r = mean radiant temperature, and
the value of A can be found from the values below as a function of the relative air speed, v_r.

v_r	< 0.2 m/s (<40 fpm)	0.2 to 0.6 m/s (40 to 120 fpm)	0.6 to 1.0 m/s (120 to 200 m/s)
A	0.5	0.6	0.7

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(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX D—COMPUTER PROGRAM FOR CALCULATION OF PMV-PPD

(Reference: Annex D of ISO 7730. Used with permission from ISO. For additional technical information and an I-P version of the equations in this appendix, refer to item 6 in References, Section 8, the ASHRAE Thermal Comfort Tool CD. The ASHRAE Thermal Comfort Tool allows for IP inputs and outputs, but the algorithm is implemented in SI.)

```
10 REM  'Computer program (BASIC) for calculation of
20 REM  'Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD)
30 REM  'in accordance with ISO 7730
40 CLS: PRINT "DATA ENTRY"                                  : 'data entry
50 INPUT " Clothing                                  (clo)"; CLO
60 INPUT " Metabolic rate                            (met)"; MET
70 INPUT " External work, normally around 0          (met)"; WME
80 INPUT " Air temperature                           ( C )"; TA
90 INPUT " Mean radiant temperature                  ( C )"; TR
100 INPUT " Relative air velocity                    (m/s)"; VEL
110 PRINT " ENTER EITHER RH OR WATER VAPOR PRESSURE BUT NOT BOTH"
120 INPUT " Relative humidity                        ( % )"; RH
130 INPUT " Water vapor pressure                     ( Pa)"; PA
140 DEF FNPS (T) = exp(16.6536-4030.183/(TA+235))           : 'saturated vapour
pressure, KPa
150 IF PA=0 THEN PA=RH*10*FNPS (TA)                         : 'water vapour pressure,
Pa
160 ICL = .155 * CLO                                        : 'thermal insulation of
the clothing in m2K/W
170 M   = MET * 58.15                                       : 'metabolic rate in W/m2

180 W   = WME * 58.15                                       : 'external work in W/m2
190 MW = M - W                                              : 'internal heat
production in the human body
200 IF ICL < .078 THEN FCL = 1 + 1.29 * ICL ELSE FCL=1.05+.645*ICL
205                                                         : 'clothing area factor
210 HCF=12.1*SQR (VEL)                                      : 'heat transf.
coefficient by forced convection
220 TAA = TA + 273                                          : 'air temperature in
Kelvin
230 TRA = TR + 273                                          : 'mean radiant
temperature in Kelvin
240 '------ CALCULATE SURFACE TEMPERATURE OF CLOTHING BY ITERATION-----
250 TCLA = TAA + (35.5-TA) / (3.5*(6.45*ICL+.1))
255 'first guess for surface temperature of clothing
260 P1 = ICL * FCL                                          : 'calculation term
270 P2 = P1 * 3.96                                          : 'calculation term
280 P3 = P1 * 100                                           : 'calculation term
290 P4 = P1 * TAA                                           : 'calculation term
300 P5 = 308.7 - .028 * MW + P2 * (TRA/100) ^ 4             : 'calculation term
310 XN = TCLA / 100
320 XF = XN
330 N=0                                                     : 'N: number of
iterations
340 EPS = .00015                                            : 'stop criteria in
iteration
350 XF = (XF+XN) / 2
355 'heat transf. coeff. by natural convection
360 HCN=2.38*ABS(100*XF-TAA)^.25
370 IF HCF>HCN THEN HC=HCF ELSE HC=HCN
380 XN=(P5+P4*HC-P2*XF^4) / (100+P3*HC)
390 N=N+1
400 IF N > 150 then goto 550
410 IF ABS(XN-XF) > EPS then goto 350
420 TCL=100*XN-273                                          : 'surface temperature of
the clothing
430 '--------------------HEAT LOSS COMPONENTS ---------------------------------
435 'heat loss diff. through skin
440 HL1 = 3.05*.001*(5733-6.99*MW-PA)
445 'heat loss by sweating (comfort)
450 IF MW > 58.15 THEN HL2 = .42 * (MW-58.15)
    ELSE HL2 = 0!
```

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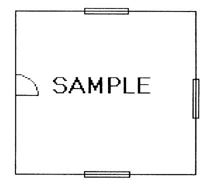
```
455 'latent respiration heat loss
460 HL3 = 1.7 * .00001 * M * (5867-PA)
465 'dry respiration heat loss
470 HL4 = .0014 * M * (34-TA)
475 'heat loss by radiation
480 HL5 = 3.96*FCL*(XN^4-(TRA/100)^4)
485 'heat loss by convection
490 HL6 = FCL * HC * (TCL-TA)
500 '-------------------------- CALCULATE PMV AND PPD -------------------------
505 'thermal sensation trans. coeff.
510 TS = .303 * EXP(-.036*M)  + .028
515 'predicted mean vote
520 PMV = TS * (MW-HL1-HL2-HL3-HL4-HL5-HL6)
525 'predicted percentage dissat.
530 PPD=100-95*EXP(-.03353*PMV^4-.2179*PMV^2)
540 goto 570
550 PMV = 99999!
560 PPD=100
570 PRINT:PRINT "OUTPUT"
580 PRINT " Predicted Mean Vote                 (PMV) : "
          ;: PRINT USING "###.###"; PMV
590 PRINT " Predicted Percent of Dissatisfied   (PPD) : "
          ;: PRINT USING "###.###"; PPD
600 PRINT: INPUT "NEXT RUN  (Y/N) "  ; R$
610 IF (R$="Y" OR R$="y") THEN RUN
620 END
```

EXAMPLE—Values used to generate the comfort envelope in Figure 5.2.1.1.

Run	Air Temp.		RH	Radiant Temp.		Air Speed					PPD
#	°F	C	%	°F	C	FPM	m/s	Met.	CLO	PMV	%
1	67.3	19.6	86	67.3	19.6	20	0.10	1.1	1	-0.5	10
2	75.0	23.9	66	75.0	23.9	20	0.10	1.1	1	0.5	10
3	78.2	25.7	15	78.2	25.7	20	0.10	1.1	1	0.5	10
4	70.2	21.2	20	70.2	21.2	20	0.10	1.1	1	-0.5	10
5	74.5	23.6	67	74.5	23.6	20	0.10	1.1	0.5	-0.5	10
6	80.2	26.8	56	80.2	26.8	20	0.10	1.1	0.5	0.5	10
7	82.2	27.9	13	82.2	27.9	20	0.10	1.1	0.5	0.5	10
8	76.5	24.7	16	76.5	24.7	20	0.10	1.1	0.5	-0.5	10

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

INFORMATIVE APPENDIX E— THERMAL ENVIRONMENT SURVEY

THERMAL ENVIRONMENT SURVEY	Survey Number:
WHITE SECTIONS TO BE FILLED IN BY OCCUPANT	Surveyor's Name:
1. Occupant's Name: **2. Date:** **3. Time:** **4. Approx. Outside Air Temperature (°F or °C):** **5. Sky:** ❑ Clear ❑ Mixed (Sun & Clouds) ❑ Overcast **6. Seasonal Conditions** ❑ Winter ❑ Spring ❑ Summer ❑ Fall	**11. Occupant Location in Area** (Place an "X" in the approximate place where you most often work.) 
7. Occupant's Clothing Please refer to the attached Table 1. Place a check mark next to the articles of clothing that you are currently wearing as you fill out this sheet. If you are wearing articles of clothing not listed in the table, please enter them into the space provided below. Article: Article:	**SURVEYOR'S USE ONLY** Clothing Insulation Summary: Total I_{cl} = ____________ clo
8. Occupant Activity Level (Check the one that is most appropriate) 1. ❑ Reclining 2. ❑ Seated Quite 3. ❑ Office, school 4. ❑ Standing Relaxed 5. ❑ Light Activity Standing 6. ❑ Medium Activity, Standing 7. ❑ High Activity	**Metabolic Rates (met)** 1. 0.8 met 2. 1.0 met 3. 1.2 met 4. 1.2 met 5. 1.6 met 6. 2.0 met 7. 3.0 met

9. Equipment (Equipment adding or taking away from the heat load.)		
Item (computers, copiers, lighting, fans, etc.)	**Quantity**	**Total Heat Added/ Subtracted**

10. General Thermal Comfort (Check the one that is most appropriate) 1. ❑ Hot 2. ❑ Warm 3. ❑ Slightly Warm 4. ❑ Neutral 5. ❑ Slightly Cool 6. ❑ Cool 7. ❑ Cold	Thermal Sensation Scale 1. + 3 2. + 2 3. + 1 4. 0 5. – 1 6. – 2 7. – 3
General Environment Comments:	**Area Summary:**
	Room/Building Type:
	Outside Relative Humidity: %
	Thermostat Setting: °F or °C
	Humidity setpoint: %
	Total Number of Occupants:

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TABLE 1
Clothing Ensembles

Description	
Trousers, short-sleeve shirt	
Trousers, long-sleeve shirt	
Trousers, long-sleeve shirt plus suit jacket	
Trousers, long-sleeve shirt plus suit jacket, vest, T-shirt	
Trousers, long-sleeve shirt plus long sleeve sweater, T-shirt	
Trousers, long-sleeve shirt plus long sleeve sweater, T-shirt plus suit jacket, long underwear bottoms	
Knee-length skirt, short-sleeve shirt (sandals)	
Knee-length skirt, long-sleeve shirt, full slip	
Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	
Ankle-length skirt, long-sleeve shirt, suit jacket	
Walking shorts, short-sleeve shirt	
Long-sleeve coveralls, T-shirt	
Overalls, long-sleeve shirt, T-shirt	
Insulated coveralls, long-sleeve thermal underwear tops and bottoms	
Athletic sweat pants, long-sleeve sweatshirt	

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

INFORMATIVE APPENDIX F—BIBLIOGRAPHY

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POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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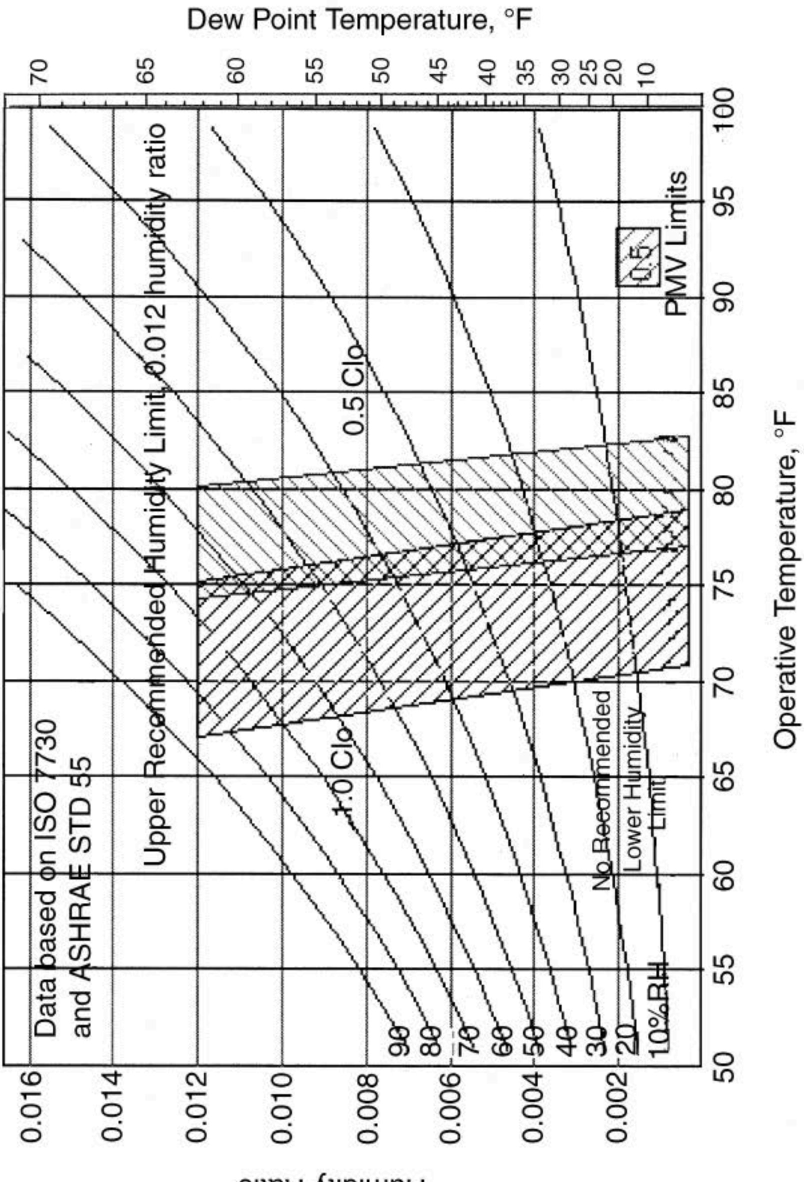
UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

STEPHEN McCOLLUM, and SANDRA McCOLLUM, individually, and STEPHANIE KINGREY, individually and as independent administrator of the Estate of LARRY GENE McCOLLUM, PLAINTIFFS	§	
v.	§	CIVIL ACTION NO. 4:14-cv-3253 JURY DEMAND
BRAD LIVINGSTON, JEFF PRINGLE, RICHARD CLARK, KAREN TATE, SANDREA SANDERS, ROBERT EASON, the UNIVERSITY OF TEXAS MEDICAL BRANCH and the TEXAS DEPARTMENT OF CRIMINAL JUSTICE. DEFENDANTS	§	

Plaintiffs' Consolidated Summary Judgment Response Appendix

EXHIBIT 147



Dew Point Temperature, °F
70
65
60
55
50
45
40
35
30
25
20
10
Upper Recommended Humidity Limit, 0.012 humidity ratio
0.5 Clo
1.0 Clo
0.5
PMV Limits
Data based on ISO 7730
and ASHRAE STD 55
No Recommended
Lower Humidity
Limit
90
80
70
60
50
40
30
20
10%RH
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
Humidity Ratio
50
55
60
65
70
75
80
85
90
95
100
Operative Temperature, °F

UNITED STATES DISTRICT COURT
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STEPHEN McCOLLUM, and SANDRA McCOLLUM, individually, and STEPHANIE KINGREY, individually and as independent administrator of the Estate of LARRY GENE McCOLLUM, PLAINTIFFS	§	
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Plaintiffs' Consolidated Summary Judgment Response Appendix

EXHIBIT 148

ANSI/ASHRAE 55-1992
Including ANSI/ASHRAE Addendum 55*a*-1995
(Supersedes ANSI/ASHRAE 55-1981)

ASHRAE® STANDARD

AN AMERICAN NATIONAL STANDARD

Thermal Environmental Conditions for Human Occupancy

Approved by the ASHRAE Standards Committee July 1, 1992; by the ASHRAE Board of Directors July 2, 1992; and by the American National Standards Institute October 30, 1992. ANSI/ASHRAE Addendum 55*a*-1995 was approved by the ASHRAE Standards Committee January 28, 1995; by the ASHRAE Board of Directors February 2, 1995; and by the American National Standards Institute April 14, 1995.

ASHRAE Standards are updated on a five-year cycle; the date following the standard number is the year of ASHRAE Board of Directors approval. The latest copies may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329.

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1791 Tullie Circle, NE • Atlanta, GA 30329

TABLE 2
Clothing Insulation Values for Typical Ensembles

Ensemble	I_{cl} (clo)
1. briefs; knit, short-sleeve sport shirts; walking shorts; belt; calf-length socks; hard-soled shoes	0.4
2. panties; broadcloth, short-sleeve shirt; A-line, knee-length skirt; pantyhose; thongs/sandals	0.5
3. briefs; broadcloth, long-sleeve shirt; long fitted trousers; belt; calf-length socks; hard-soled shoes	0.6
4. panties; full slip; broadcloth, short-sleeve shirt; belted A-line dress; long-sleeve cardigan sweater; pantyhose; hard-soled shoes	0.7
5. panties; broadcloth, long-sleeve shirt; sleeveless round-neck sweater; thick walking shorts; belt; thick knee socks; hard-soled shoes	0.7
6. panties; half-slip; broadcloth, long-sleeve blouse; single-breasted suit jacket; A-line, knee-length skirt; pantyhose; thongs/sandals	1.0
7. briefs; thermal long underwear top; thermal long underwear bottoms; flannel, long-sleeve shirt; overalls; calf-length socks; hard-soled shoes	1.0
8. briefs; broadcloth, long-sleeve shirt; single-breasted suit jacket; tie; straight, long fitted trousers; calf-length socks; hard-soled shoes	1.0
9. briefs; t-shirt; broadcloth, long-sleeve shirt; long-sleeved, round-neck sweater; thick, straight, long, loose trousers; belt; calf-length socks; hard-soled shoes	1.0
10. panties; broadcloth, long-sleeve shirt; thick vest; thick, single-breasted suit jacket; thick, A-line, knee-length skirt; pantyhose; hard-soled shoes	1.0
11. briefs; t-shirt; broadcloth, long-sleeve shirt; thick vest; thick, single-breasted suit jacket; thick, straight, long, loose trousers; belt; calf-length socks; hard-soled shoes	1.2
12. briefs; t-shirt; flannel, long-sleeve shirt; work jacket; belt; work pants; calf-length socks; hard-soled shoes	1.3
13. flannel, long-sleeve, long nightgown; thick, long-sleeve, wrap, long robe; slippers	1.7

TABLE 3
Optimum and Acceptable Ranges of Operative Temperature for People During Light, Primarily Sedentary Activity (≤1.2 met) at 50% Relative Humidity and Mean Air Speed ≤0.15 m/s (30 fpm)[a]

Season	Description of Typical Clothing	I_{cl} (clo)	Optimum Operative Temperature	Operative Temperative Range (10% Dissatisfaction Criterion)
Winter	heavy slacks, long-sleeve shirt and sweater	0.9	22°C 71°F	20-23.5°C 68-75°F A
Summer	light slacks and short-sleeve shirt	0.5	24.5°C 76°F	23-26°C 73-79°F X
	minimal (briefs)	0.05	27°C 81°F	26-29°C 79-84°F X

[a]Other than clothing, there are no adjustments for season or sex to the temperatures of Table 3. For infants, certain elderly people, and individuals who are physically disabled, the lower limits of Table 3 should be avoided.

(b) the rate (degrees per hour) at which the temperature is increasing,
(c) the rate (degrees per hour) at which the temperature is decreasing, and
(d) the peak-to-peak amplitude of the fluctuation.

5.1.5.1 Temperature Cycling If the peak cyclic variation (time period less than 15 minutes) in operative temperature exceeds 1.1°C (2°F), the rate of temperature change shall not exceed 2.2°C/h (4°F/h). There are no restrictions on the rate of temperature change if the peak-to-peak difference is 1.1°C (2°F) or less.

5.1.5.2 Temperature Drifts or Ramps Temperature drifts and ramps are monotonic, steady, *noncyclic* operative temperature changes. Drifts refer to passive temperature changes of the enclosed space, and ramps refer to actively controlled temperature changes. The maximum allowable

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STEPHEN McCOLLUM, and SANDRA McCOLLUM, individually, and STEPHANIE KINGREY, individually and as independent administrator of the Estate of LARRY GENE McCOLLUM, PLAINTIFFS	§ § § § § § §	
v.	§ § §	CIVIL ACTION NO. 4:14-cv-3253 JURY DEMAND
BRAD LIVINGSTON, JEFF PRINGLE, RICHARD CLARK, KAREN TATE, SANDREA SANDERS, ROBERT EASON, the UNIVERSITY OF TEXAS MEDICAL BRANCH and the TEXAS DEPARTMENT OF CRIMINAL JUSTICE. DEFENDANTS	§ § § § § § §	

Plaintiffs' Consolidated Summary Judgment Response Appendix

EXHIBIT 149

From: Jason Clark
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Sent: 7/16/2014 8:40:47 AM
Subject: Clip#2 - Texas Prisons are Super Hot This Time of Year

WOAI Radio – San Antonio
Posted Wednesday, July 16th 2014 @ 5am
It's pretty uncomfortable out there, with temperatures in the high nineties to triple digits all this week. Good thing you're not in prison.
Newsradio 1200 WOAI reports none of the cell blocks on Texas state prison units have traditional air conditioning. Some have air conditioning in infirmaries and psychiatric units, but for the inmate in the five by nine cell, it really is 'the hot box' this time of year.
"We provide water, we provide ice, we provide fans," said Robert Hurst, a spokesman for the Texas Department of Criminal Justice in Huntsville.
He says the state recently invested in a new cooling system for some of the prison units, buying 28 so called 'Cool System' fans, which are similar to the large fans you see behind the benches at football games.
He says those fans are being placed in the 'day rooms where inmates congregate, but only in seven prison units.
"Those facilities were chosen because they house offenders who are new to the system." Hurst says.
A group of prison guards and prisoners rights groups have repeatedly sued the state prison system, saying forcing inmates to live in triple digit summer temperatures without air conditioning amounts to cruel and inhuman punishment, and point out that a hog barn at a prison farm near Huntsville is air conditioned. Guards also complain that they have to share the hot conditions with the inmates, leading to unsafe working conditions.
The state says air conditioning prison units, many of which are a century old, would cost in the billions of dollars, and making prisoners more comfortable is not a priority for Texas taxpayers.